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BUBBLES IN POLYHEDRAL GEODES FROM SWAZILAND.

By Edgar D. Mountain.

(With four Text-figures.)

(Read March 19, 1941.)

In 1934 Mr. T. Kelly obtained from the tin mines in Mbabane, Swaziland, of which he is the owner, a number of polyhedral specimens of quartz, about half a dozen of which were noteworthy in possessing cavities containing both liquid and gas. These specimens he distributed amongst his friends and other people interested, and in this way one of the best specimens came into my possession. The following July I paid a visit to the mines and obtained a few additional but inferior specimens, some of which possessed cavities, but none contained bubbles. The manager of the mines told me that one or two specimens containing bubbles had been broken open and that the liquid tasted like ordinary water, while the gas appeared to possess no particular features.

All these specimens had come from a spot a mile or two above the plant where the gravels were being hydraulically treated. They were associated with masses of pegmatite material lying loose on the surface, and unfortunately not one had been found in place. The assumption is that the specimens are derived from pegmatite or granite, which constitutes the country rock, but the exact mode of occurrence can only be surmised.

In addition to these specimens, Dr. J. Willemse of the Geological Survey lent me a few others and generously offered to allow me to use any of them up for investigation, if necessary. These latter included the largest specimen I have seen enclosing a bubble, as shown on the left-hand side of fig. 1. It will be noticed that the bottom right-hand portion has been broken off, and was originally separated from the bottom left-hand portion that remains by a deep gash which penetrated half-way through the specimen from the bottom upwards. Another of the specimens lent had been sectioned parallel to one of its surfaces.

The specimens generally range in size from one to two inches across, but the large one just referred to is four inches in maximum diameter. As stated, they are polyhedral, normally without re-entrant angles, and the faces are disposed without any regularity whatever, nor do the interfacial angles correspond to any extent as between different individuals.

The only suggestion of a re-entrant feature is the occurrence on one or two specimens of deep parallel-sided gashes with slightly stepped sides faintly resembling cleavage, as seen in fig. 1. The faces are remarkably plane, giving in many cases a dispersion of the reflected image amounting to no more than a few seconds of arc. On the other hand, these faces carry a remarkable set of minor irregularities over the whole surface (fig. 2) which prevent the reflexion of a really sharp image.

These surface features at first sight strongly suggest the appearance of frost on windows. They consist, however, of two distinct types of pattern.

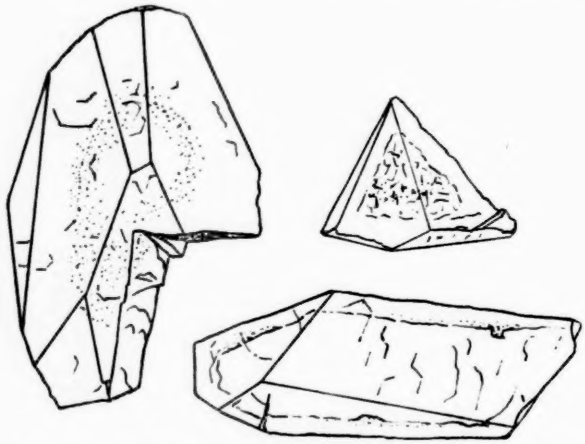

Fig. 1.—Three typical specimens, the largest being 4 inches in length. Two of them contain bubbles.

In the first place, the surfaces show a trace of stepping, the height of the steps being of the order of 0·1 mm., while the directions of the steps on any surface are clearly aligned parallel to the sides of a regular hexagon. There appears to be no relationship between the shape of the face and the orientation of the steps, nor do the steps on adjacent faces bear any relationship to each other. The steps, in fact, stop short at the margin of each face and are not continued over the edge.

The second set of features are those which recall frost patterns and are definitely related to these steps. They consist of rows of parallel shallow fluted cones which may reach a length of over 5 mm. The principal fluting on each cone is radial, but it is associated with a transverse system of fluting perpendicular to the axis of the cone and parallel to the sides of the hexagon. Parallel cones, moreover, are similarly oriented, so that the pattern as a whole possesses threefold symmetry. It is suggested

that the steps are similar in character to growth-lines, while the cones possess a radial structure due to rapid crystallisation and reflect the three-fold symmetry of the principal axis of quartz.

Specimens already broken clearly showed that the crystalline material, with the exception of one or two tiny grains of pyrite, consisted entirely of quartz or, in part, chalcedony, in the form of roughly parallel individuals pointing inwards as in a geode or quartz vein. In some of the specimens two generations of quartz are visible, the surfaces between them being

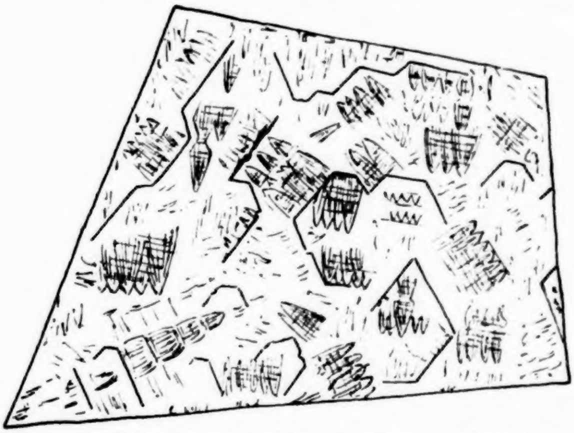

FIG. 2.—General appearance of surface of specimen in reflected light. Magnification, × 12 diameters.

sprinkled with tiny reddish spots of iron oxide. In some cases quartz crystals meet in the centre without any cavity, the opposing crystals interdigitating. Where a cavity exists, the crystals show well-defined terminal faces of the primary rhombohedron, generally modified only by very small faces of the negative rhombohedron, while traces of the first order prism also occur. While the vertical axes of crystals growing inwards from the same outer surface show only a rough parallelism, small groups of crystals often exhibit perfect, or nearly perfect, parallel growths. Oppositely oriented crystals also occur in contact, thus resembling twins on the prism face. No faces of the trigonal bipyramid or the trapezohedron have been observed. A section parallel to one of the outer surfaces of a specimen showed that the optic axes of the various individuals were inclined as much as 25° to the normal to the section, though generally at a much smaller angle.

A thin section cut perpendicular to an outer surface shows some interesting features (fig. 3). In this specimen there are two distinct zones

of crystal growth, both beginning with finely crystalline material and becoming coarser towards the centre, where there is a suggestion of a third fine-grained zone. The fine portion of the outer zone, some 15 μ wide, consists of subparallel quartz fibres perpendicular to the outer surface and with faint banding spaced at about 4 μ parallel to the surface. In the coarser portion, the individual crystals reach a length of 2 mm. and a width of 1 mm. Encrusting the terminal faces of these crystals are flamboyant fibres arranged roughly normal to the faces, with negative

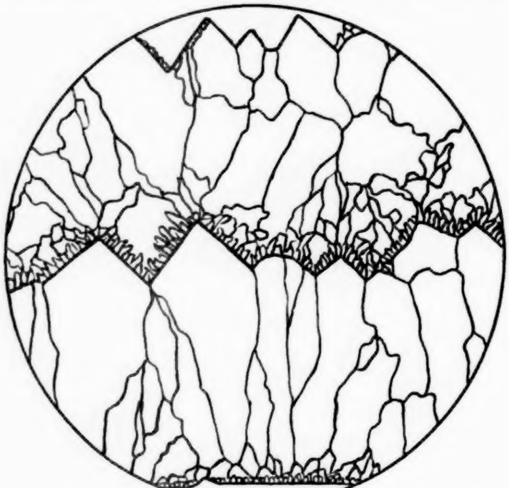

FIG. 3.—Camera-lucida drawing of section of typical quartz crust observed between crossed nicols. Outer surface at bottom. Magnification, $\times 20$ diameters.

elongation and relatively low refractive index, presumably chalcedony. In ordinary light with high-power objectives they show a remarkable series of fine bands about 2 μ in width, about 25 bands in all, which are parallel to the crystal faces and are no doubt colloform in character; they bend round the apices of the crystals, but meet in sharp angles in the re-entrants between adjacent crystals. These fibres pass into the quartz of the second zone, which, though showing a tendency towards subparallel arrangement, has more of a mosaic texture. The terminal faces of the crystals lining the cavity carry in places a thin crust of finely crystalline chalcedony with brown iron stains. The deep gashes previously mentioned are lined, like the outer surfaces, with fine-grained material, which indicates that they were originally filled with some platy substance, since removed in solution.

As already stated, of the various specimens which had come into my possession only two contained bubbles of gas and liquid, and it was eventually decided to sacrifice the one which belonged to me. Early attempts, under the supervision of Dr. A. H. Spong, to drill the specimen under mercury proved unsuccessful because in all cases the bit collapsed under the influence of the mercury before sufficient progress had been made. After further unsuccessful attempts to procure a bit that would be unaffected by mercury, it was decided, on the advice of Mr. F. A. Bannister of the British Museum, to adopt a different method of attack. Accordingly details were prepared with the assistance of Dr. A. S. Galloway, who had in the meantime taken the place of Dr. Spong in the Chemistry Department of Rhodes University College.

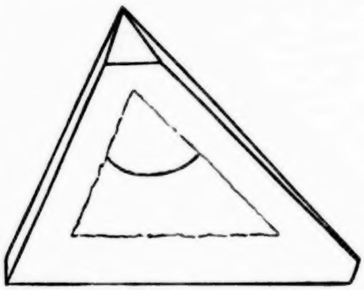

FIG. 4.—Drawing from photograph of specimen broken open, showing apparent thickness of crust, and shape and size of bubble. Magnification, × 1½ diameters.

The specimen concerned (fig. 4) has a maximum diameter of 4·5 cm., originally weighed 27·30 grm., and had a volume of 11·37 c.c. The volume of the cavity was estimated as 1·5 c.c., and that of the bubble of gas as 0·4 c.c. by external measurements; the thickness of the quartz casing was about 4 mm. One surface was ground down on a carborundum lap until the casing was very thin, the difficulty being that the inner surface was very irregular. This surface was then perforated by a screw-clamp under mercury, and the escaping liquid and gas collected by means of a funnel and collecting tube over the mercury. Some of the liquid remained adhering to the surface of the funnel and tube, but all the gas was satisfactorily collected. The volume of the liquid which rose above the mercury was 0·55 c.c. and that of the gas 14·1 c.c., measured over 36·6 cm. of mercury and equivalent to 6·04 c.c. at N.T.P.

Next, the liquid and gas were separated. A small evacuated tube with taps at each end was attached to the collecting tube with a grease joint and the gas drawn off until the surface of the liquid just rose to the lower tap. Some of the liquid was then tested. On evaporating 0·2 grm. to dryness, there was no weighable residue, while spot tests gave positive reactions only for carbon-dioxide and acidity. By the capillator method, using bromo-thymol blue, the pH value was determined as 6·6.

The gas was then tested over mercury. A little caustic potash was introduced which absorbed about 0·2 c.c. of carbon-dioxide, and sub-

sequently a potash solution of pyrogallol absorbed 1·5 c.c. of oxygen. The remaining gas, 5·2 c.c. in volume, was transferred to a eudiometer and sparked with oxygen, and proved to consist entirely of nitrogen. The volume composition of the gas was thus nitrogen 75, oxygen 22, and carbon-dioxide 3 per cent.

The empty specimen was then filled with water to the level at which it previously stood, and was also filled completely, in order to determine more accurately the original volumes of the liquid and gas. This gave 1·57 c.c. for the total volume of the cavity and 1·14 c.c. for that of the liquid, so that the volume of the gas was 0·43 c.c., results agreeing closely with the earlier figures. Thus, neglecting the effect of gases dissolved in the water, 6·04 c.c. of gas were confined in a space of 0·43 c.c., and therefore under a pressure of some 14 atmospheres.

One final point emerged upon examination of the empty specimen. A few small rounded blackish spots were seen on the quartz crystals lining the cavity and slightly embedded in the quartz. They are about 0·05 mm. in diameter, and under the microscope are seen to consist of radiating bunches of tiny needles which are almost opaque but transmit yellowish brown light. The refractive index is high, the needles have straight extinction, and it is probable that they consist of rutile. Unfortunately they are too minute for further tests. The quartz crust is practically colourless, and there is no coating of iron oxides on the interior as is the case of the specimens picked up already broken.

Unfortunately the investigation had not thrown much light on the origin of these specimens, and the account given here must be regarded merely as a description of their principal characters. It seems certain that they are of the nature of geodes formed by deposition from a silica gel, while the plane outer surfaces suggest that they are epimorphous in character; that is to say, that the original cavity occurred between crystal faces of different individuals, whether quartz, feldspar, or some other mineral, and that deposition took place on these crystal faces. The pressure observed within the cavity is no indication of the conditions under which the silica gel was introduced, as any original pressure must have been modified by the process of consolidation.

Cavities in which crystals point inwards are said to be drusy or miarolitic, while the word geode is generally restricted to such structures which, on weathering, separate from the enclosing rock. Potato-stone is a popular name given to rounded masses with these features, and they occasionally contain small quantities of water. Quartz crystals in granite frequently contain tiny hollows, generally microscopic in size, and sometimes bounded by plane faces, while bubbles are not uncommon in them. Such bubbles, however, appear to consist usually of carbon-dioxide and water, or even

liquid carbon-dioxide. Yet another type of specimen more closely resembling the specimens described is that known as enhydros, which consists of hollow rounded nodules of chalcedony of comparable dimensions and partly or wholly filled with water. The best known specimens come from Uruguay and consist of amygdales weathered out of basalt, differing from the Swaziland material in having been formed at the Earth's surface, and thus more or less at atmospheric pressure.

ACKNOWLEDGMENT.

The Council desires to acknowledge the receipt of a grant from Rhodes University College in aid of publication.

ABNORMALITIES AND VARIATIONS IN THE VASCULAR SYSTEM OF *XENOPUS LAEVIS* (DAUDIN).

(A Paper from the University of Cape Town.)

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Department of Zoology, University of Cape Town.

(Communicated by R. S. ADAMSON.)

(With eleven Text-figures.)

(Read March 19, 1941.)

CONTENTS.

INTRODUCTION.

Much literature exists on the question of abnormalities in the vascular system of the Anura, but so far only one instance has been recorded for *Xenopus laevis*, that of the persistence of the right posterior cardinal vein (Ortlepp, 1918). This leads O'Donoghue (1931) to conclude that major abnormalities in the blood system are rare in *Xenopus*. It is surprising that further instances have not been recorded, for *Xenopus* is widely used in South Africa for laboratory work and it is the author's experience that the percentage of abnormalities is particularly high.

O'Donoghue (1931), in his useful paper on "Abnormalities in the Blood Vascular System of the Anura," summarised and classified all the literature on abnormalities up to that period, as well as describing a number of new instances. Many of these he was able to explain in terms of ontogeny, but others he found inexplicable. Since then other records have appeared (Jäger, 1937, and O'Donoghue, 1933).

The use of the terms "abnormality" and "variation" has already been discussed in detail by O'Donoghue (1931), and it may suffice to say that the terms are used here in an exactly similar sense. The various

abnormalities encountered are described below, and certain common variations in the blood system are also briefly discussed.

Material and Technique.

In the work required for my previous paper (1941) several abnormalities were encountered, and since then more have come to light. All the animals were collected in the neighbourhood of Cape Town and brought into the laboratory during the years 1938 to 1940. I am grateful to Dr. E. F. J. de Jager for drawing my attention to specimens 5, 8, and 11. Where possible, the animals were injected through the conus with Ranvier's carmine-gelatine.

In examples 2 and 3 the hearts were microtomised and diagrams made by means of a Leitz "Panphot" (text-figs. 3 and 4).

Abnormalities.

A. *Arterial.*

1. *Accessory Branch of the Carotid Arch* (text-fig. 1).—This artery was present in approximately 42 per cent. of the animals. Out of 38 specimens examined, of which 11 were males and 27 females, it was found to occur in 16 cases—6 males and 10 females. It is a narrow artery, and its branches can only be readily dissected in injected specimens. It leaves the a. carotis interna immediately before the latter turns dorsalwards and forwards over the posterior end of the hyoid arch; it then runs outwards along the dorsal surface of m. petrohyoideus to the region of the angle of the lower jaw, where it finally branches up.

The following branches are common, but one or more is usually wanting:—

(*a*) A small branch to the oesophagus, arising near origin from a. carotis interna.

(*b*) One or two branches to m. petrohyoideus.

(*c*) A branch passing between m. cucullaris and m. depressor mandibulae to the thymus gland.

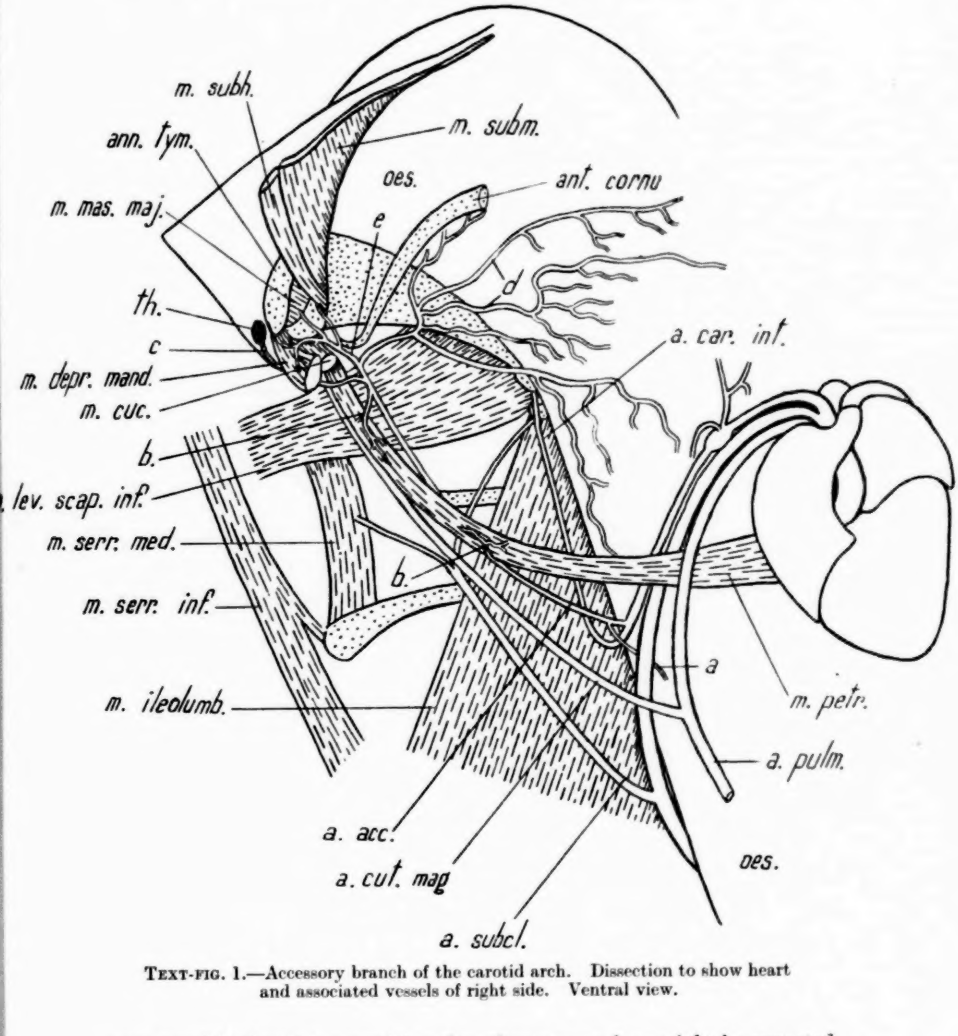
(*d*) A pharyngeal branch ramifying on the lateral wall of the pharynx.

(*e*) Muscular branches to m. depressor mandibulae, m. subhyoideus, and mm. masseter major and minor.

(*f*) A small branch breaking up on the inner surface of the annulus tympanicus.

This accessory branch of the carotid arch, so far as the author is aware, has not been previously recorded in any Anura, but is so common in *Xenopus* that it is only with some hesitation classed here as an abnormality.

It seems unlikely that only a certain percentage of the animals should have acquired a new artery of so consistent and well-developed a character, but

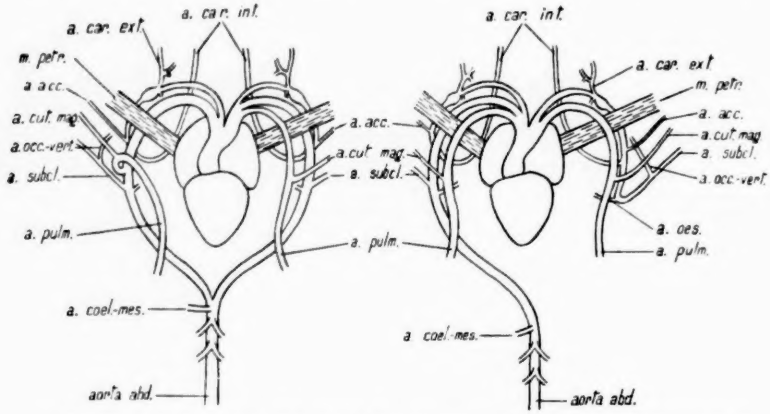


TEXT-FIG. 1.—Accessory branch of the carotid arch. Dissection to show heart and associated vessels of right side. Ventral view.

more possible that it is a persistent larval artery, such as might be expected in a notoriously neotenic animal.

2. *Missing Pulmo-cutaneous Arch* (text-fig. 2, left).—The specimen in which this abnormality occurred was a small mature female, which was injected for dissection and subsequently found to have no pulmo-cutaneous arch on the right side.

The right a. cutanea magna and a. pulmonalis arose by a common stem from the right aorta thoracica immediately anterior to the origin of the a. subclavia. The right aorta thoracica appeared to be slightly distended, but all other arteries were normal in every way. The accessory



TEXT-FIG. 2.—Left: A scheme of the main arteries of the body in specimen 2, in which there is a missing pulmo-cutaneous arch on the right side. Right: A scheme of the arteries in specimen 3, in which there is a missing aortic arch on the left side. Both in ventral view.

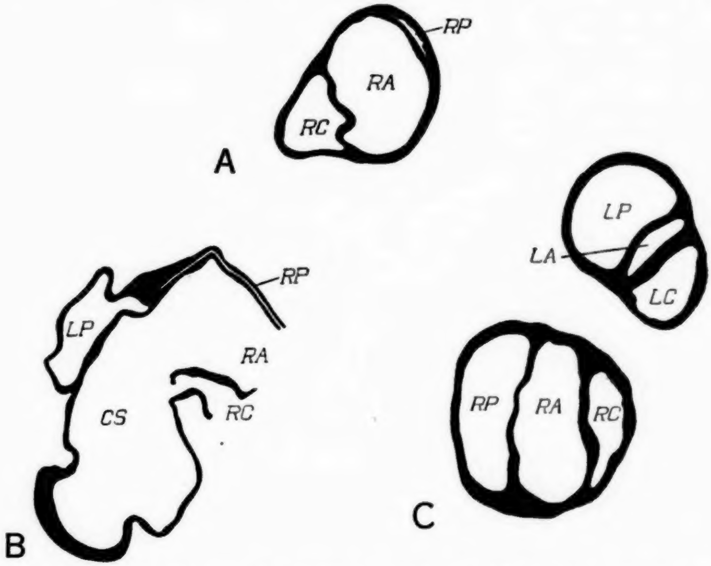
branch of the carotid arch described in example 1 was present on both sides. Both lungs were normal in size.

Microtomised material revealed that the cavity of the right aortic arch was undivided throughout its length, but in the dorsal wall of the right side of the truncus arteriosus there was present a small, vestigial right pulmonary arch filled with injection mass (text-fig. 3, A and B). This canal when traced forwards ended blindly in the wall of the right truncus, and when traced backwards joined the left pulmonary canal to form the cavum pulmo-cutaneum in the normal way. The histology of the wall appeared to be normal, since all the usual layers were present, including the endothelium.

The only other abnormality recorded in any way resembling the above is one described for *Rana esculenta* by Mozejko (1909), which lacked a pulmo-cutaneous arch on the left side. In this case, however, the left

lung was only about one-third of the normal size and was without a direct arterial supply.

By way of explanation there seem to be two possibilities, for both of which it is assumed that the right pulmo-cutaneous arch degenerated during embryonic life, due to injury or some other cause. If this arch degenerated early in life, the pulmo-cutaneous branch, when it developed,



TEXT-FIG. 3.—A: Diagram of a section through the right truncus arteriosus in specimen 2, showing the vestigial right pulmo-cutaneous canal (RP). B: Slightly diagonal section through the truncus arteriosus in specimen 2, showing the right vestigial pulmo-cutaneous canal (RP) leaving the left pulmo-cutaneous canal (LP). RP is in longitudinal section and LP in transverse. C: Section through the right and left trunci arteriosi of specimen 3, showing the vestigial left aortic canal (LA).

would merely have attached itself to the next nearest artery, *i.e.* the paired dorsal aorta. If, however, the 6th embryonic arch was injured *after* the attachment of the pulmo-cutaneous branch, it is possible that the right ductus Botalli remained open in the adult and conveyed blood from the paired dorsal aorta to the right a. pulmo-cutanea. The peculiar ventral twist in the latter artery at the point of origin from the right aortic arch favours the second alternative.

It is interesting at this stage to compare the experiments of Figge (1934) on Amblystoma. This author showed that by ligation of the 6th

(pulmonary) arch in Amblystoma a condition could be produced which exactly resembles the abnormal condition described above, *i.e.* in which there was degeneration of the ventral part of the pulmonary arch and persistence of the ductus Botalli. Amblystoma larvæ, in which both pulmonary arches were so treated, always failed to metamorphose. Figge also draws attention to the fact that in *Necturus*, a perennibranchiate Urodele, the ventral part of the 6th arch is lacking altogether.

3. *Missing Aortic Arch* (text-fig. 2, right).—The animal in question was a mature male frog and was obtained from among some junior class dissections. On the left side the aorta thoracica was entirely absent, but the carotid arch, after giving off the accessory branch described in example 1 and the internal carotid artery, continued backwards for a short distance and gave rise to the a. oesophagea and the a. subclavia in approximately their normal positions. On the right side the three arches arose normally, the aortic arch continuing backwards to the mid-dorsal line, where it gave off the a. coeliaco-mesenterica and then proceeded as the aorta abdominalis.

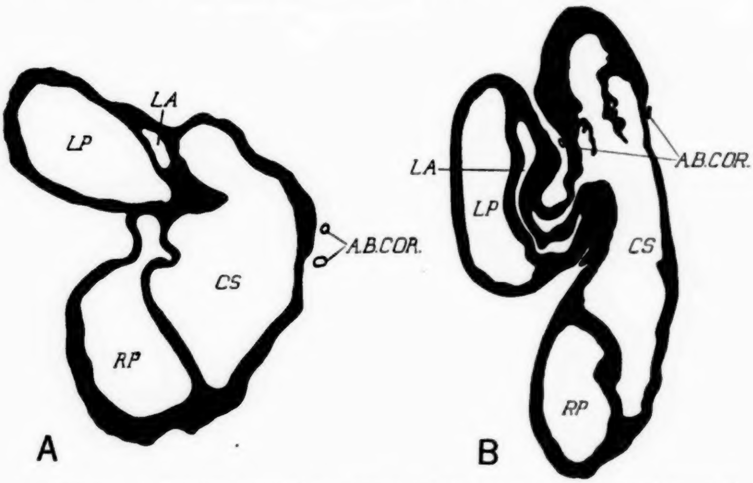
On microtomising the heart and the points of origin of the vessels it was found that an under-sized left aortic canal was present in the truncus arteriosus (text-fig. 3, C). It left the cavum systemo-caroticum in the usual way and was continued forwards for a short distance between the left pulmo-cutaneous and carotid canals, to end blindly in the wall of the carotid arch at the point where the latter emerged from the pericardium. The shape of the truncus arteriosus was slightly affected, a typical dent usually present between the already separated left aortic canal and the rest of the cavum systemo-caroticum being absent (text-fig. 4). The structure of the rest of the bulbus cordis and truncus arteriosus, as well as the histology of the blind arch, appeared to be normal.

A somewhat similar example was described by O'Donoghue (1931) for *Rana temporaria*. In his specimen, however, the proximal part of the aortic arch persisted and gave origin to the a. subclavia and a. occipito-vertebralis on its particular side.

In the instance described here there are again two possible explanations. In the first place, the 4th embryonic arch on the left side and part of the paired dorsal aorta may have degenerated early in life, and the left subclavian become attached to the next nearest artery—in this case the left a. carotis interna. On the other hand, if the 4th embryonic arch became lost *after* the attachment of the a. subclavia, the latter could have maintained its blood-supply by way of the 3rd embryonic (carotid) arch and the persistent ductus caroticus.

A definite instance of a persistent ductus caroticus connecting the carotid and aortic arches is quoted by O'Donoghue (1933).

Miscellaneous Arterial Abnormalities.—Under this heading several abnormal conditions are described for which it is not proposed to offer explanations. It must be borne in mind, however, that during embryonic life the three arterial arches on each side are in communication with one another through the paired dorsal aorta. Injuries to different parts of this system could be compensated for by a large variety of adjustments.



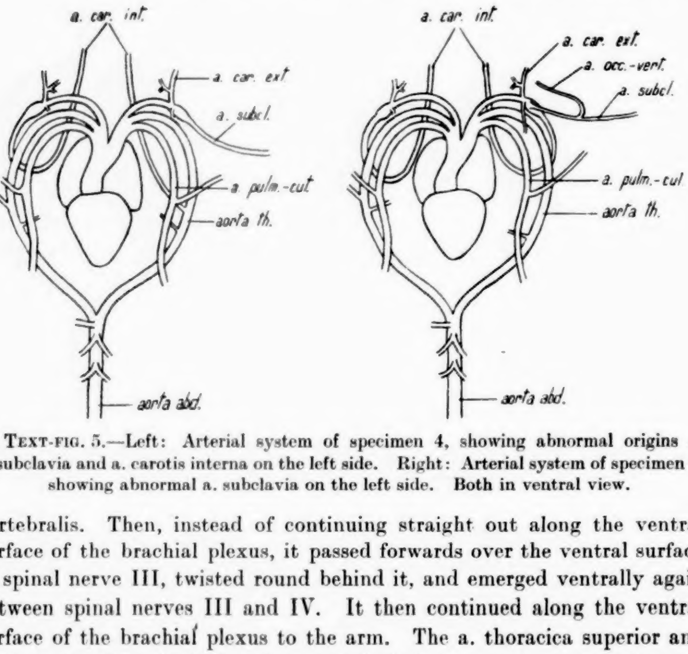
TEXT-FIG. 4.—Sections through the trunci arteriosi of A: the abnormal heart of specimen 3, with its vestigial left aortic canal (LA); and B: a normal heart in approximately the same region for comparison. In both hearts the "cavum pulmo-cutaneum" has divided into its right and left halves (RP and LP), and the left aortic canal (LA) has become separated from the "cavum systemo-caroticum" (CS).

Specimen 4. *Subclavian and internal carotid arteries interchanged* (text-fig. 5, left). A case was reported from a junior class dissection in which the a. subclavia and the a. carotis interna on the left side were interchanged. Unfortunately, the sex of the specimen was not recorded. The left carotid arch normally gave rise to the a. carotis externa, and from the distal end of the carotid gland it proceeded straight outwards to the fore limb as the a. subclavia. The left aorta thoracica gave rise to the a. carotis interna from the point where the a. subclavia normally originates. The origin of the a. occipito-vertebralis and other branches of the a. subclavia were not recorded.

Specimen 5. *Subclavian artery arising from carotid gland* (text-fig. 5, right). Another abnormality found among class dissections was that of a mature male frog in which the left a. subclavia arose from the carotid

gland at the same level as the origin of the a. carotis externa. The carotid arch then continued normally as the a. carotis interna. The left aorta thoracica was unbranched save for the small a. oesophagea. The a. occipito-vertebralis was given off by the a. subclavia as usual.

Specimen 6. Twisted subclavian artery. This was a large mature female which was injected for dissection purposes. The dissection is described as follows, as viewed from the ventral surface. The right a. subclavia left the aorta in the normal manner and gave off the a. occipito-



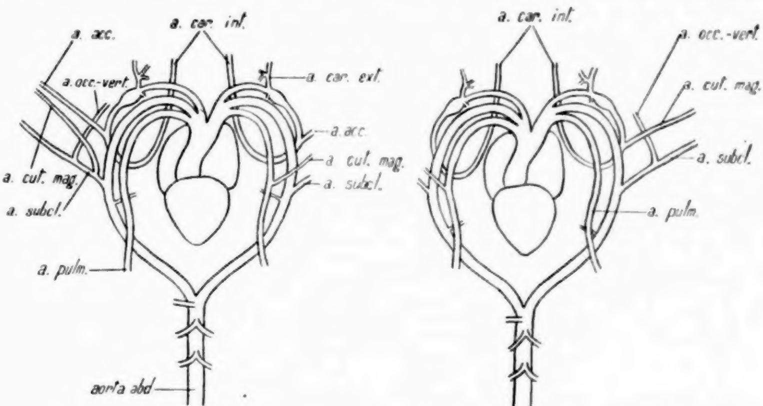
Text-fig. 5.—Left: Arterial system of specimen 4, showing abnormal origins of a. subclavia and a. carotis interna on the left side. Right: Arterial system of specimen 5, showing abnormal a. subclavia on the left side. Both in ventral view.

vertebralis. Then, instead of continuing straight out along the ventral surface of the brachial plexus, it passed forwards over the ventral surface of spinal nerve III, twisted round behind it, and emerged ventrally again between spinal nerves III and IV. It then continued along the ventral surface of the brachial plexus to the arm. The a. thoracica superior and a. thoracica abdominalis left the a. subclavia by a common root and passed to their destinations anteriorly *behind* spinal nerve III and posteriorly *behind* spinal nerve IV respectively. All other branches of the a. subclavia were normal.

Specimen 7. Cutaneous artery arising from subclavian (text-fig. 6, left). This specimen was a well-developed, mature male frog, and was obtained from among junior class dissections. The right side of the animal was abnormal in that the a. cutanea magna was given off by the a. subclavia close to its point of origin from the aorta thoracica. The pulmo-cutaneous arch on that side passed straight to the lung without

branching. The accessory branch of the carotid arch described in example 1 was present on both sides, but all other arteries were normal.

Specimen 8. *Cutaneous artery arising from carotid arch* (text-fig. 6, right). Another case of an abnormal a. cutanea magna among junior class dissections was brought to my notice, and again the animal was a mature male frog. Once more the pulmo-cutaneous arch (this time on the left side) passed, without branching, direct to the lung. The a. cutanea magna in this case, however, arose from the a. carotis interna, as the



TEXT-FIG. 6.—Left: Arterial system of specimen 7, showing the abnormal origin of the right a. cutanea magna. Right: Arterial system of specimen 8, showing the abnormal origin of the left a. cutanea magna. Both in ventral view.

latter passed backwards ventrally over the hyoid apparatus. The accessory branch of the carotid arch described in example 1 was not present, and all other arteries were normal.

Specimens 9 *and* 10. *Abnormal origin of a. occipito-vertebralis.* In two animals, one a large mature female and another whose sex was not recorded, the a. occipito-vertebralis was observed to have an abnormal origin. In both cases it was the left side that was affected, and the artery in question arose from the aorta thoracica independently of the a. subclavia.

These cases are interesting in that the condition resembles that normally present in *Rana*.

Specimen 11. *Abnormal aa. oesophageae.* An animal was noticed (a mature male) in which the a. oesophagea on the right side was entirely absent, while that of the left side originated from the a. subclavia instead of from the aorta thoracica.

It is noteworthy that this animal possessed particularly well-developed

gland at the same level as the origin of the a. carotis externa. The carotid arch then continued normally as the a. carotis interna. The left aorta thoracica was unbranched save for the small a. oesophagea. The a. occipito-vertebralis was given off by the a. subclavia as usual.

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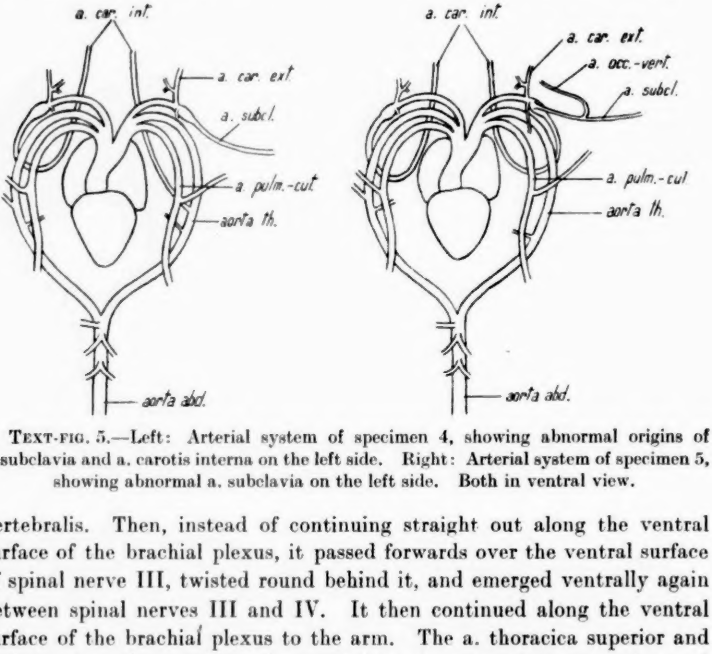


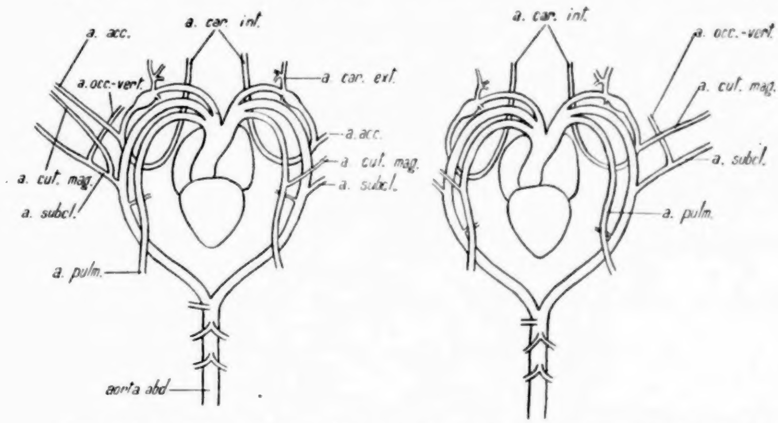
TEXT-FIG. 5.—Left: Arterial system of specimen 4, showing abnormal origins of a. subclavia and a. carotis interna on the left side. Right: Arterial system of specimen 5, showing abnormal a. subclavia on the left side. Both in ventral view.

vertebralis. Then, instead of continuing straight out along the ventral surface of the brachial plexus, it passed forwards over the ventral surface of spinal nerve III, twisted round behind it, and emerged ventrally again between spinal nerves III and IV. It then continued along the ventral surface of the brachial plexus to the arm. The a. thoracica superior and a. thoracica abdominalis left the a. subclavia by a common root and passed to their destinations anteriorly *behind* spinal nerve III and posteriorly *behind* spinal nerve IV respectively. All other branches of the a. subclavia were normal.

Specimen 7. *Cutaneous artery arising from subclavian* (text-fig. 6, left). This specimen was a well-developed, mature male frog, and was obtained from among junior class dissections. The right side of the animal was abnormal in that the a. cutanea magna was given off by the a. subclavia close to its point of origin from the aorta thoracica. The pulmo-cutaneous arch on that side passed straight to the lung without

branching. The accessory branch of the carotid arch described in example 1 was present on both sides, but all other arteries were normal.

Specimen 8. *Cutaneous artery arising from carotid arch* (text-fig. 6, right). Another case of an abnormal a. cutanea magna among junior class dissections was brought to my notice, and again the animal was a mature male frog. Once more the pulmo-cutaneous arch (this time on the left side) passed, without branching, direct to the lung. The a. cutanea magna in this case, however, arose from the a. carotis interna, as the



TEXT-FIG. 6.—Left: Arterial system of specimen 7, showing the abnormal origin of the right a. cutanea magna. Right: Arterial system of specimen 8, showing the abnormal origin of the left a. cutanea magna. Both in ventral view.

latter passed backwards ventrally over the hyoid apparatus. The accessory branch of the carotid arch described in example 1 was not present, and all other arteries were normal.

Specimens 9 *and* 10. *Abnormal origin of a. occipito-vertebralis.* In two animals, one a large mature female and another whose sex was not recorded, the a. occipito-vertebralis was observed to have an abnormal origin. In both cases it was the left side that was affected, and the artery in question arose from the aorta thoracica independently of the a. subclavia.

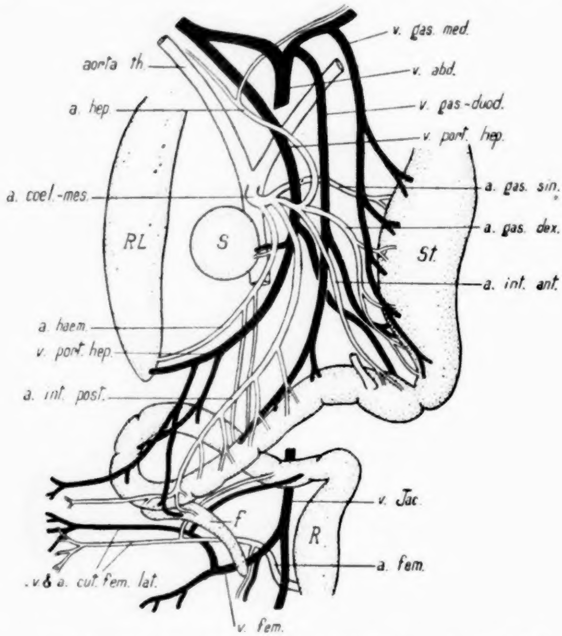
These cases are interesting in that the condition resembles that normally present in *Rana*.

Specimen 11. *Abnormal aa. oesophageae.* An animal was noticed (a mature male) in which the a. oesophagea on the right side was entirely absent, while that of the left side originated from the a. subclavia instead of from the aorta thoracica.

It is noteworthy that this animal possessed particularly well-developed

oesophageal arteries originating from the a. cutanea magna on each side (a condition which occurs occasionally as described below, p. 22, branch (*b*)), and these were able to substitute for the missing right a. oesophagea.

Specimen 12. *Abnormal oviducal arteries.* In one specimen, a mature female frog, two of the aa. urogenitales supplying the right oviduct were



TEXT-FIG. 7.—Dissection of specimen 13 in ventral view, showing the arteries and veins of the gut with their abnormal pulmonary connections and accessory cutaneous branches.

seen to arise from branches of the a. femoralis. One was a branch of the a. circumflexa ilium externa and the other a branch of an a. muscularis iliaca.

Specimen 13. *Additional pulmonary veins and arteries* (text-fig. 7). A very peculiar mature male frog was encountered which possessed an additional pulmonary artery and vein on the right side, coupled with an abnormal condition of the intestine and arrangement of the blood-vessels in this region.

The tip of the right lung was attached to the intestine by tough

strands of connective tissue through which passed the additional pulmonary artery and vein. The artery was a branch of the a. haemorrhoidalis (of the a. coeliaco-mesenterica), and the vein was a branch of the v. portae hepatis.

On the right side of the body the intestine was drawn down and attached to the side of the body-wall by tough connective tissue at the point where the a. cutanea femoris lateralis and the v. cutanea femoris lateralis pass through the muscular body-wall to the skin. Both these blood-vessels had abnormal branches to the posterior region of the intestine.

Also concerned in the attachment of the intestine was a piece of fatty tissue, which appeared to have become separated from the right fatty body. It was supplied by branches of the blood-vessels of the gut, *i.e.* v. intestinalis and a. intestinalis posterior. From these latter, small branches also passed to the skin and anastomosed with the v. cutanea magna and the a. cutanea magna.

Quite a number of instances of additional pulmonary arteries and veins arising from the a. coeliaco-mesenterica and hepatic portal vein respectively have been described by Jäger (1937), O'Donoghue (1931), Crawshay (1906), Warren (1898, 1900, and 1902), Shore (1901), Mudge (1899), and others. So far no satisfactory morphogenetic explanation has been offered. In the specimens previously recorded, however, the abnormalities were apparently not associated with any other irregularities of body structure.

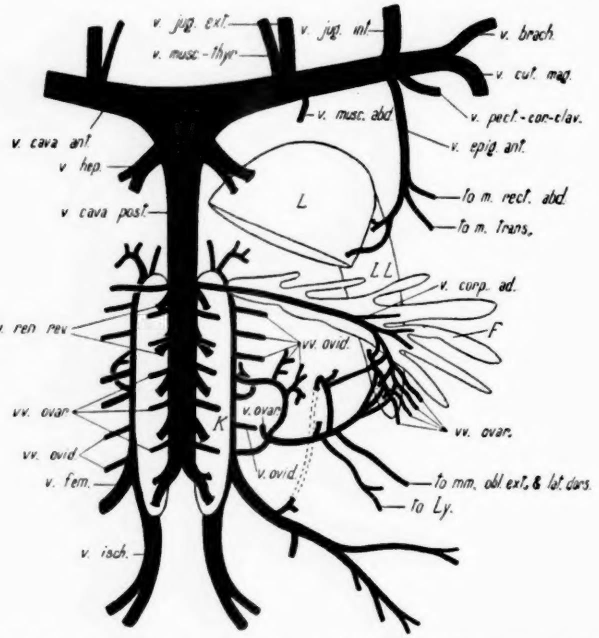
B. *Venous.*

Additional Pulmonary and Hepatic Veins.—One instance of an additional pulmonary vein has already been mentioned in specimen 13, where the vein was so closely associated with the corresponding artery that it was thought best to describe them together. Another very abnormal frog is described below (specimen 14).

Specimen 14 (text-fig. 8). A large mature female. The v. epigastrica anterior in the normal animal is made up of branches draining the musculus rectus abdominis and m. transversus, and runs forwards to join the v. subclavia. In specimen 14 the v. epigastrica anterior on the left side received three branches in the region of the diaphragm: one from m. transversus, one from m. rectus abdominis, and a third coming from the mesentery connecting the lung and liver on that side (the ventral pulmonary fold) and receiving a branch from each of the two latter organs.

In addition, the fatty body and part of the ovary on the left side adhered to the tip of the lung. A network of blood-vessels connected the three organs and anastomosed with the vein from the fatty body and the veins from the ovary. Four small veins left this network and ran to the

dorsal body-wall, where they united to form a larger vein, which also received branches from the muscles of the body-wall (m. iliacus externus, m. latissimus dorsi, and m. obliquus externus), from an enlarged lymph gland about the size of a small pea lying between the lateral body-wall and the skin, from the ovary, and from the oviduct. It discharged its blood through three veins, one of which joined an oviducal vein and so passed to



TEXT-FIG. 8.—Diagram of venous system of specimen 14, showing the accessory pulmonary veins and abnormal venous network on the left side. Ventral view.

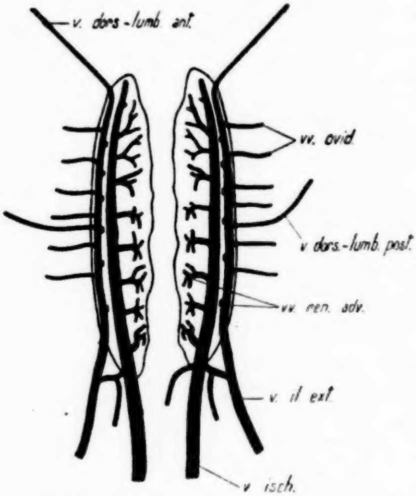
the v. Jacobsonii, another entered the v. Jacobsonii direct, and the third joined the v. iliaca externa.

By this extraordinary system of veins, therefore, the left lung was connected in the first place with the anterior vena cava, and in the second place with the posterior vena cava and the renal portal system. No accessory pulmonary arteries were present, the arterial system being normal in every way.

The case most nearly resembling this is described by O'Donoghue (1931, p. 215) for *Rana temporaria*, where an "accessory pulmonary vein arises from the apex of the left lung and passes posterad through the body

cavity to enter Jacobson's vein about one-third of the way down the kidney." Shore (1901) has also described a venous connection between Jacobson's vein and the left lung.

Specimen 15. This example was a large mature female in which the most anterior muscular branch of the v. abdominalis ran outwards along the first inscriptio tendinea, continued through the mesentery suspending lung and liver (*i.e.* the ventral pulmonary fold), and dived into the outer



TEXT-FIG. 9.—Renal portal system of specimen 16, dorsal view, showing doubling of v. Jacobsonii.

posterior corner of the liver. This is by no means an uncommon condition, since it has been observed in five other specimens—four female and one male. In one of these (a female) there was also a small connection with the lung.

Specimens 16 *and* 17. *Double renal portal veins* (text-fig. 9). Two large, mature female frogs possessed double renal portal veins (on both sides in the first case, on the left only in the other). The v. ischiadica and v. iliaca externa continued forwards independently over the dorsal surface of the kidney instead of joining to form a single v. Jacobsonii. At the posterior end of the kidney, where the two veins normally join, there was a very small branch connecting them. From the continuation of the v. iliaca externa opened a series of small, short vv. renales advehentes, and into it opened the v. dorso-lumbalis anterior, v. dorso-lumbalis

posterior, and six oviducal veins. The v. oesophagea was absent. The v. ischiadica gave off a series of better developed and branched vv. renales advehentes. So far the two specimens were entirely similar. In specimen 16 an artery from the dorsal body-wall joined the commissural vessel on each side, and another joined the v. ischiadica on the right side. Other branches of the v. ischiadica and v. iliaca externa were normal.

This abnormality is interesting in that the greater size of the vein continued from the v. ischiadica, emphasises the point already brought out in my former paper (1941), that in *Xenopus* it is the postaxial vein that conveys the main blood-stream from the leg, and not the preaxial vein as in *Rana*.

O'Donoghue (1933) has observed a condition in *Rana temporaria* where the left renal portal vein, after the junction of femoral and ischiadic, bifurcates, thus forming a double renal portal vein. Other such cases of doubling or looping of the renal portal have been recorded by O'Donoghue (1931) and Collinge (1915) for *Rana temporaria*, but none show such complete division of the femoral and ischiadic blood-streams.

Specimen 18. *Double dorso-lumbral vein.* In this animal, a large mature female, the v. dorso-lumbalis anterior was double. One branch entered the v. Jacobsonii at the anterior end of the kidney and drained the region of the dorsal body-wall in front of spinal nerve 6. The other branch arose from the body-wall between spinal nerves 6 and 7 and joined the v. Jacobsonii about 7 mm. further back than the first. The v. dorso-lumbalis posterior was present and normal.

Variations.

A. *Arterial.*

There is naturally always a certain amount of variation in the smaller branches of the arterial system. Some of the larger branches also vary enormously, as for example the aa. urogenitales and aa. lumbales. These have already been described in my former paper.

Branches of a. cutanea magna.—In *Rana esculenta*, described in detail by Gaupp (1896), this artery passes unbranched through the body cavity to the posterior angle of the head, where it divides up to supply the skin. In *Xenopus*, however, there are usually several small branches in this region which vary considerably from one animal to the next. They may be reduced to four main elements enumerated as follows:—

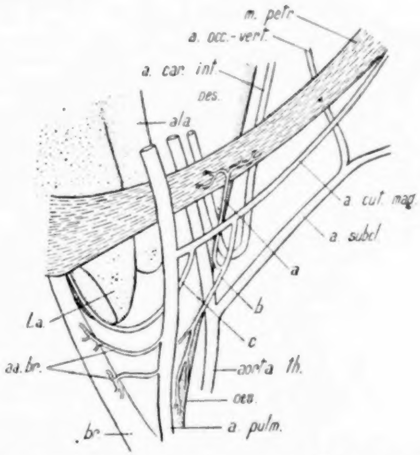
(*a*) A branch to m. petrohyoideus (may be double).

(*b*) A branch to the oesophagus (usually anastomoses with one of the oesophageal branches of a. carotis externa).

(*c*) A branch passing inwards and forwards to enter the larynx with the bronchus (most common in male animals).

(*d*) A branch to the bronchus, taking the place of the one that normally leaves the a. pulmonalis.

Specimen 19, figured in text-figure 10, is a typical example possessing the first three elements.



Text-fig. 10.—Dissection to show the branches of left a. cutanea magna in specimen 19. Ventral view.

Specimen 20 was an extreme case. There were two branches present, one of which divided into two arteries, both supplying m. petrohyoideus, while the other passed to the lateral surface of the oesophagus. The latter not only anastomosed with an oesophageal branch of a. carotis externa, but passed along the dorsal surface of the stomach to anastomose with a branch of a. coeliaco-mesenterica (a. gastrica sinistra s. dorsalis) and with the second a. urogenitalis.

B. *Venous.*

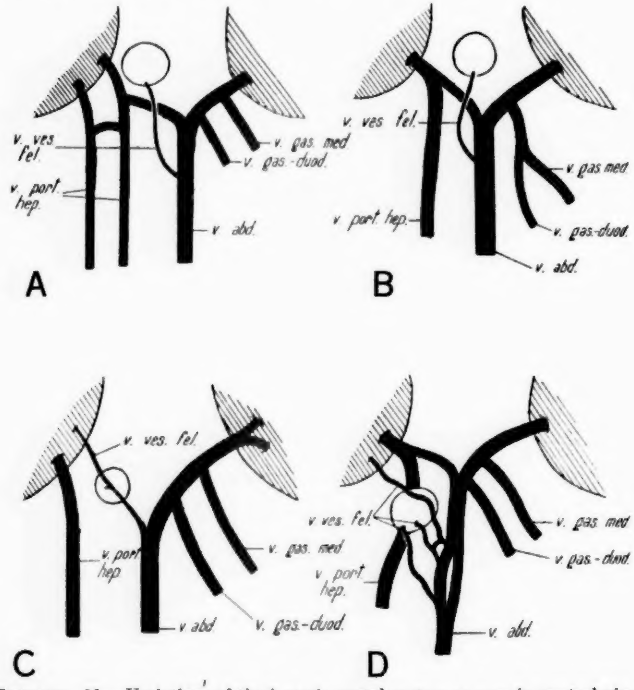
Variations are far commoner in the venous than in the arterial system, and most of them have already been described in my previous paper. These variations affect the following:—

The relative sizes of the left and right v. muscularis-thyroidea, where the right vein is usually weaker than the left or absent altogether.

The relative sizes of the left and right v. jugularis externa, where the right vein is usually stronger than the left.

The position of the v. muscularis abdominis, which usually joins the v. cava anterior opposite the v. jugularis externa, but may be placed more laterally or more mesially, and may anastomose with the v. retrosternalis or v. epigastrica anterior.

The v. epigastrica anterior, which may anastomose with the v. muscularis abdominis or v. abdominalis.



Text-fig. 11.—Variations of the hepatic portal system as seen in ventral view. For description see text.

The v. pectoralis-coraco-clavicularis, which may enter the v. subclavia as two separate branches—v. coraco-clavicularis and v. pectoralis.

The vv. hepaticae, which vary slightly in number and position.

The vv. renales revehentes, vv. genitales, and vv. corporis adiposi, which vary in number.

Apart from these, variations in the hepatic portal system are frequent, and examples such as those figured (text-fig. 11) commonly occur in class dissections. In A the v. portae is double. In B the v. gastro-duodenalis and v. gastrica media join before entering the ramus sinister of the

v. abdominalis. In C the ramus dexter of the v. abdominalis is absent, and the v. portae runs directly into the right lobe of the liver. In D there is a loop in the v. abdominalis and an extra branch to the gall-bladder and right lobe of the liver. These variations are the most common, but others have been observed, such as a commissural vessel connecting the ramus sinister of the v. abdominalis with the ramus dexter, and a specimen with a detached piece of the left liver and an extra branch of the v. abdominalis supplying it.

Discussion.

It is difficult to estimate the percentage of abnormalities in *Xenopus laevis*, since no systematic search has as yet been made. Examples have merely been recorded as they happened to present themselves in junior class work as well as in research specimens. It is nevertheless noteworthy that out of 55 specimens dissected by the author in detail, 9 possessed major abnormalities (omitting that of the carotid arch described in example 1). This gives an approximate 16 per cent., which is extraordinarily high compared with O'Donoghue's statement (1931) that in his experience in *Rana temporaria* the number varies from 0 in 260 to 3 in 60. In other members of the Anura abnormalities are apparently even less common.

An interesting point is that, in *Xenopus*, although smaller variations of size and position are far commoner in the venous system, major abnormalities appear to be more frequent among the arteries. No cases of abnormal hearts have so far been observed; apparently such abnormalities would be more easily noted in microtomised hearts than in macroscopic preparations.

A remarkable aspect is that of the mixing of the arterial and venous blood in these abnormal creatures. In some cases the a. cutanea magna, which normally carries venous blood, is supplied by the carotid arch, in others by the aortic arch. In one case the a. carotis interna, which normally bears the purest arterial blood to the head and brain, is supplied by the mixed blood-stream of the aortic arch. Yet in all cases the adult is perfectly normal in appearance. It is significant, however, that at no time has such a major abnormality in the arterial system been encountered on both sides of the body.

In the present state of our knowledge it must suffice to ascribe the high percentage of abnormalities among the Aglossa, and the ability of the abnormal animals to survive, to the neotenic nature of the group. In only a few cases has it been possible to offer explanations based on ontogenetic grounds.

Summary.

1. Eighteen major abnormalities in the blood-system of *Xenopus laevis* are described and, where possible, explanations are offered in terms of the ontogeny.

2. The common variations in the blood-system are summarised and described.

3. Whereas in *Xenopus* the smaller variations occur more frequently among the veins than among the arteries, the reverse is true for the major abnormalities.

4. The percentage of abnormalities in *Xenopus* appears to be higher than that recorded for any other genus of the Anura.

5. The frequency with which abnormalities occur is believed to be associated with the neotenic nature of the Aglossa.

Acknowledgments.

The author wishes to thank Professor C. G. S. de Villiers of the University of Stellenbosch for his advice and for the use of his department's valuable collection of reprints and periodicals, and also Dr. H. Sandon of the University of Cape Town for reading the manuscript.

The Council desires to acknowledge the receipt of a grant from the University of Cape Town towards the cost of publication of this paper.

Addendum (25/2/42).

Another abnormality was discovered after this paper had gone to press, in which the posterior vena cava, instead of entering the sinus venosus, was connected to the left anterior vena cava by the persistent anterior portion of the left postcardinal vein. This is the second case of a persistent postcardinal recorded for *Xenopus*.

LIST OF ABBREVIATIONS.

Muscles.

Mm. cuc., cucullaris; *depr. mand.*, depressor mandibulae; *ileolumb.*, ileolumbaris; *lat. dors.*, latissimus dorsi; *lev. scap. inf.*, levator scapulae inferior; *mass. maj.*, masseter major; *obl. ext.*, obliquus externus; *petr.*, petrohyoideus; *rect. abd.*, rectus abdominis; *serr. inf.*, serratus inferior; *serr. med.*, serratus medius; *subh.*, subhyoideus; *subm.*, submaxillaris; *trans.*, transversus.

Arteries.

Aa. acc., accessory branch of a. carotis interna; *aorta abd.*, aorta abdominalis; *aorta th.*, aorta thoracica; *b. cor.*, bulbi cordis; *br.*, artery to bronchus; *car. ext.*, carotis externa; *car. int.*, carotis interna; *coel.-mes.*, coeliaco-mesenterica; *cut. fem. lat.*, cutanea femoris lateralis; *cut. mag.*, cutanea magna; *fem.*, femoralis; *gas. dex.*, gastrica dextra s. ventralis; *gas. sin.*, gastrica sinistra s. dorsalis; *haem.*, haemorrhoidalis; *hep.*, hepatica; *int. ant.*, intestinalis anterior; *int. post.*, intestinalis posterior; *occ.-vert.*, occipito-vertebralis; *oes.*, oesophagea; *pulm.-cut.*, pulmo-cutanea; *pulm.*, pulmonalis; *subcl.*, subclavia.

Veins.

Vv. abd., abdominalis; *brach.*, brachialis; *cava ant.*, cava anterior; *cava post.*, cava posterior; *corp. ad.*, corporis adiposi; *cut. fem. lat.*, cutanea femoris lateralis; *cut. mag.*, cutanea magna; *dors.-lumb. ant.*, dorso-lumbalis anterior; *dors.-lumb. post.*, dorso-lumbalis posterior; *epig. ant.*, epigastrica anterior; *fem.*, femoralis; *gas.-duod.*, gastro-duodenalis; *gas. med.*, gastrica media; *hep.*, hepatica; *il. ext.*, iliaca externa; *isch.*, ischiadica; *Jac.*, Jacobsonii; *jug. ext.*, jugularis externa; *jug. int.*, jugularis interna; *musc. abd.*, muscularis abdominis; *musc.-thyr.*, muscularis-thyroidea; *ovar.*, ovarica; *ovid.*, oviducalis; *pect.-cor.-clav.*, pectoralis-coraco-clavicularis; *port. hep.*, portae hepatis; *ren. adv.*, renalis advehens; *ren. rev.*, renalis revehens; *ves. fel.*, vesica fellea.

Other Abbreviations.

Ann. tym., annulus tympanicus; *ant. cornu*, anterior cornu; *br.*, bronchus; *CS*, cavum systemo-caroticum; *F*, portion of fatty body; *K*, kidney; *L*, liver; *La*, larynx; *LA*, left aortic canal; *LC*, left carotid canal; *LL*, left lung; *LP*, left pulmo-cutaneous canal; *Ly*, enlarged lymph gland; *oes.*, oesophagus; *R*, rectum; *RA*, right aortic canal; *RC*, right carotid canal; *RL*, right lung; *RP*, right pulmo-cutaneous canal; *S*, spleen; *St.*, stomach; *th.*, thymus gland.

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COLOUR VISION AND COLOUR DISCRIMINATION AMONGST THE BECHUANA.

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(Communicated by I. Schapera.)

(Read March 19, 1941.)

Introduction.

In view of the conclusions of Clements (1930) concerning the probable existence of racial differences in the incidence of colour-blindness, the investigation of this abnormality amongst the native races of South Africa becomes of interest; but, so far as it is possible to ascertain, there are no references to this subject in the literature.

This paper records observations made upon a random sampling of 981 Bechuanas, of both sexes, living in the Northern and Central Protectorate. All subjects were adult or adolescent.

Tests were made not only to detect gross degrees of colour-blindness, but also for defects in discrimination of varying degrees of saturation.

Methods.

This investigation was carried out in the field upon subjects who were, for the most part, completely illiterate and of a low mentality, and who, furthermore, have a very limited vocabulary of colour terms.

It was felt, therefore, that a colour-matching test, although perhaps old-fashioned, would give as reliable results as the use of modern methods for colour-vision examination. (Had Isihara's plates been used, for example, the subjects would have had to draw the figures that they saw. Although this does not sound difficult, it was found in practice that primitive illiterates, totally unaccustomed to drawing, very often have great trouble in reproducing even the most simple figures, even after several attempts.)

A test similar to Edridge Green's bead test was employed, coloured discs being used instead of beads, and each test disc being removed from the observer's sight after the matching had been accomplished. The test discs were five in number—pale green, rose, bright red, purple, and yellow. The discs were presented in this order, as recommended for the

Holmgren wool test by J. H. Parsons (1938). The total number of "confusion colour" discs provided was 68.

For colour discrimination, a series of similar discs, giving graded depths of green, blue, yellow, red, and violet, five discs to each colour, were employed (*cf.* Pierce, 1933).

Since the investigation was carried out in the field, the lighting conditions were naturally not identical for each batch of tests, but every effort was made to get the conditions as comparable as possible. Tests were always carried out at the same time of day, and where it was not possible to make use of a large room, such as a school class-room, examinations were made away from direct sunlight.

Results and Comments.

The results of the investigation showed that a precise classification into the two categories of normal and colour-blind was impossible, as there appear to exist degrees of defect in colour vision, ranging from confusion in matching closely similar mixtures or shades to complete inability to distinguish any colour at all.

The incidence of gross degrees of achromatopsia is shown in Table I.

Table I.

Number examined.		Colour-blind.		Per cent. of total examined.	
M.	F.	M.	F.	M.	F.
407	574	14	2	3·4	0·35

The classification of the colour-blind cases is given in Table II.

Table II.

Totally colour-blind.		Red blind (Protanopes).		Green blind (Deuteranopes).		Blue-yellow blind (Tritanopes).	
M.	F.	M.	F.	M.	F.	M.	F.
1	0	4	0	8	2	1	0

Information as to the incidence of gross degrees of colour-blindness amongst African peoples is very scanty. Clements (*op. cit.*) gave a summary

of the results of such work amongst non-European races as had been accomplished up to the time of his own publication.

In this summary, results for three small series of Congolese, Egyptians, and Nubians are given; but since the numbers examined were only 57, 80, and 50 respectively, the results, which were *nil*, 4, and 1, can scarcely be regarded as significant. In larger series (each of over 1000 subjects), throughout the world, Clements quotes percentages of colour-blind subjects ranging from 1·6 (American negroes) to 4·16 (British). The methods used are not stated, however, and it is probable that the figures are not strictly comparable.

It will be seen that the present results are well within the range quoted. The proportion between the sexes, 10 to 1, is also that usually found.

Table III.

Group A. Subjects who could not discriminate between hues.

	Number.		Per cent. of total.	
	M.	F.	M.	F.
Sub-group (I). Unable to distinguish between grey, green, and intermediate mixtures .	50	50	12·3	8·9
Sub-group (II). Unable to distinguish between purple, violet, and intermediate mixtures .	16	21	3·9	5·4
Sub-group (III). Unable to distinguish between blue, green, and intermediate mixtures .	1	0	0·25	..
Sub-group (IV). Unable to distinguish between yellow, green, and intermediate mixtures .	1	1	0·25	0·17
Group B. Subjects who could not discriminate between degrees of saturation of the same colour.				
Sub-group (V). Red	33	51	8·1	8·9
Sub-group (VI). Yellow	21	43	5·1	7·1

With regard to the incidence of the different types of colour-blindness, it is generally agreed that green blindness is commoner than red blindness, in the proportion, roughly, of 3 to 1 (Clements; v. Planta, 1928; Miles, 1929). The proportion in this series is rather less, 10 to 4.

According to Parsons (1938), blue blindness is exceedingly rare; there seemed, however, to be no doubt about the case recorded in this series. It is noteworthy that one case of blue-yellow blindness was recorded amongst the small series of Nubians referred to above.

The single case of complete achromatopsia was unable to say whether his parents (deceased) had also been colour-blind. In this case nystagmus was present, but it was not possible to test for the presence of scotomata.

The results of the colour discrimination tests are interesting with regard to the distinction between those who could not distinguish between certain hues and those unable to distinguish between degrees of saturation. Results are given in Table III.

In addition, certain individuals fell into more than one sub-group; the figures for these are given in Table IV.

TABLE IV.

Subjects falling into sub-groups.	Number.		Per cent. of total.	
	M.	F.	M.	F.
I and II.	6	5	1·5	0·9
I and V.	5	6	1·2	1·0
II and V.	1	1	0·25	0·17
I and VI.	3	8	0·73	1·4
II and VI.	0	1	..	0·17
V and VI.	0	2	..	0·34

No individual fell into more than two sub-groups. All subjects of the colour-discrimination test matched correctly colours other than those mentioned, both for hue and saturation.

It will be noted that more than 97 per cent. of the subjects unable to discriminate between hues fell into two of the four sub-groups (I and II), and that of these 73 per cent. fell into group I, and that the subjects who could not distinguish degrees of saturation could be classified into two sub-groups only, for red and yellow respectively.

These results are somewhat puzzling. As regards the large percentage who cannot distinguish between grey and green, the question immediately suggests itself: Is there any connection between this grey-green

confusion and the grey-green shade which is the prevalent colour of the Bechuanaland bush country, just as a blue shade is characteristic of the mountains of the south?

This question can, of course, only be answered by further observations.

It is also noteworthy that in the colour ranges to which the subjects are most accustomed, and which are most used in their domestic occupations, *e.g.* the identification of cattle, no mistakes were made. Probably habituation plays an important part in sharpness of discrimination, but it has not been possible to test a group of subjects whose occupation demands such habituation to a wide colour range.

The suggestion that habituation may play an important part in colour discrimination is borne out by an examination of the colour vocabulary of the Sechuana and Sekalaka tongues, both of which were spoken by the subjects of this investigation. Both are poor in colour terms. This deficiency was noticeable when subjects were asked to name colours; although, in many cases, they were able to match colours perfectly, they were at a loss to name them (*cf.* Beaglehole, 1939).

The limits of this paper forbid a philological exposition, but it may be mentioned that in both languages the word *tala* is used for the designation of blue, green, and the whole gamut of intermediate shades.

Sechuana provides qualifying phrases for the distinction of certain colours, *e.g.*, purple is designated by *botala go bontsha*, and there are separate phrases for red, crimson, and scarlet, whereas Sekalaka appears to have no such distinctions, the word *tshaba* covering the shades mentioned.

It seems likely that, as Myers (1908) suggested, a colour vocabulary is adjusted to the needs of the speakers. It will be interesting to note how the vocabulary will enlarge itself as further opportunity and need of discrimination appear.

Summary.

1. Colour-vision and colour-discrimination tests have been applied to 981 adult and adolescent Bechuanas, of both sexes, living in the Central and Northern Protectorate.

2. Of these subjects, 16, or 1·6 per cent., were found to be colour-blind.

3. A notable proportion were unable to distinguish between certain hues and also between different degrees of saturation of the same colour.

4. The findings are briefly discussed.

I am indebted to the Principal Medical Officer of this Protectorate for permission to publish this record.

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THE LETABA HOT SPRING.

By Leslie E. Kent.

(Communicated by S. H. Haughton.)

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(With one Map.)

(Read March 19, 1941.)

In the Low Veld of the north-eastern Transvaal there is a solitary hot spring which, although well-known and held in high repute locally for its medicinal value, has not been previously described or even recorded. This spring, which it is proposed to name the "Letaba Hot Spring," rises about half a mile south of the Groot Letaba River on the farm Eiland 134 in the Letaba district. The position is given by latitude 23° 39′ S. and longitude 30° 40′ E.

The spring was known to and utilised by the native inhabitants both as a bath and a source of salt long before the European settlement. This salt was obtained by lixiviating the mud through which the water issued and evaporating the resultant solution over open fires in clay pots. The heaps of extracted earth scattered over an area of about half a square mile near the edge of the vlei beside the Mamatzapi watercourse are relics of this industry.

The spring is nowadays readily accessible, being only 300 yards south of the main road beside the Groot Letaba River. Buses of the South African Railways Road Motor Service operating from Rubbervale, the nearest station, traverse this road on Wednesdays on their weekly circuit. On the outward run "Hotbaths halt" is 33 miles from Rubbervale, on the inward part of the circuit 25 miles.

The distances by road to Letsitele and Tzaneen are 26 and 44 miles respectively.

Climate.

Owing to the unpleasantly hot Low Veld summer and to the prevalence of malaria, the spring is frequented during the mild winter months May to August.

No adequate meteorological records exist for the immediate vicinity of the spring. Rainfall records have been kept on some of the neighbouring farms—La Cotte, 8 miles up the river to the west; Nondwene, 13 miles

down the river to the east; Platveld, 12 miles south-south-east; and Chester, 10 miles south-west (6). The mean maximum and minimum temperatures were recorded at Platveld for the period March 1929 to December 1932 and at Chester from January 1934 to December 1938 (9).

Owing, however, to war-time censorship regulations this information may not be quoted.

Description of the Spring.

The spring issues in a small vlei only slightly below the general level of the surrounding flat bushveld, which slopes gently down to the Groot Letaba River. At the eyes the altitude is 1380′ (adjusted aneroid reading). The only notable topographical feature in the vicinity is the Black Hills range, along which lies the eastern boundary of the farm Eiland. At the northern end of this ridge the Eiland Trigonometrical Survey Station stands at an altitude of 1709′.

There are five separate active eyes forming the Letaba Hot Spring and these are arranged along a straight line which strikes at 9° east of north. For convenience in description they may be numbered from north to south 1, 2, 3, 4, 5, the distance between 1 and 5 being 30 yards. The strongest flow comes from 3, and a pool 16 feet by 13 feet and 4 to 5 feet in depth has been dug over eyes 2 and 3. Planks line the sides of the pool and sand has been strewn over the bottom.

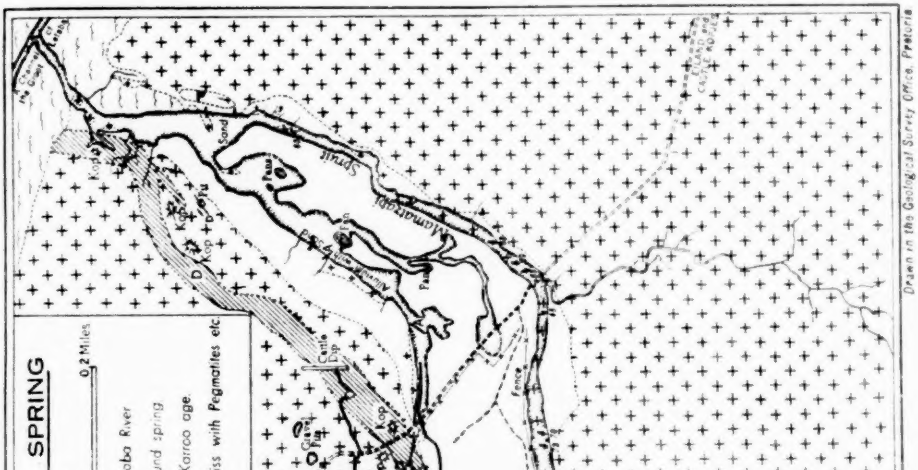
When undisturbed, the water in this pool is perfectly clear, and irregular surges of gas can be seen bubbling up through the sand at short intervals. As shown on the map (p. 37) the overflow from the pool passes along a furrow to a small dam overgrown with reeds, whence it is drawn to irrigate lands on the vlei.

Green algae grow on the sides of the pool where undisturbed. Most surprising is the presence of many small fish, which enter and leave the hot pool from the dam *via* the furrow. They are apparently quite unaffected by the hot water, and swim gaily amongst the gas bubbles.

A reed fence surrounds this pool and primitive dressing-rooms are provided.

Of the remaining eyes, which also emit a little gas intermittently, 1 is very weak and is not used, but 4 and 5 are fairly strong and are on occasion used as mud baths.

The immediate vicinity of the spring is a water-logged bog into which a rod may be pushed for 8 feet at least without encountering any resistance. In former years, before the water was drained off for irrigation, the marshy part of the vlei was much more extensive and the spring water seeped into the Mamatzapi watercourse. Many years ago the vicinity of this salt marsh was a favourite resort of game, and the former native inhabitants


LETABA HOT SPRING
SCALE.
Miles 0 0.1 0.2 Miles
Alluvium of Groot Letaba River
Soils forming vlei around spring.
Dolerite of probable Karroo age.
Old Granite and Gneiss with Pegmatites etc.
Amphibolite
Vlei
Feed Dam
Bath
Wall
Drawn in the Geological Survey Office, Pretoria
Surveyed by L. E. Kent.

are reputed to have despatched many an elephant trapped in the mire.

The mud of this bog when dry has some of the properties of peat, since it is combustible.

Seventy yards south of the pool in the same line as the five active eyes, a small moist depression was noted in the sandy bed of a dry water-course. Cold saline water was encountered here at a depth of about a foot, but as this water-level is about 6 feet below that of the pool, this cold "eye" is probably due to seepage. Seventy yards still farther south a dry, shallow, small mud hole in a tributary of the same dry watercourse is also taken to be a former "seepage eye."

Although the spring is privately owned, a few rondawels have been built in the vicinity for the accommodation of the hundred or so persons who specially visit the spring each winter to take the cure.

Flow.

The flow of the spring was roughly gauged at $\frac{1}{6}$ of a cusec (about 91,000 gallons or 409 cubic metres per 24 hours). This figure was obtained by measurements made in the furrow near the point of emergence from the bath, and as seepage losses, vegetal discharge and the flows of the eyes 1, 4, and 5 are not included, the combined true yield must be appreciably greater. According to Meinzer's classification this spring is of 5th magnitude discharge.

In the bath the gas is exuded at the rate of approximately 400–500 litres per hour.

Temperature Measurements.

Temperature readings taken about 6 inches under the sand over eye 3 in the pool are as follows:—

October 3, 1936	42° C. (107·6° F.)
June 13, 1937	40·4° C. (104·7° F.)
July 6, 1937	40·6° C. (105·1° F.)
September 23, 1937	41·3° C. (106·3° F.)
October 6, 1937	40·5° C. (104·9° F.)

The water at the surface of the pool is from 1° to 3° C. lower.

On September 23, 1937, the following temperatures were recorded from the subordinate eyes:—

Eye.	Surface Temperature.	Temperature $2\frac{1}{2}$ feet below the Surface.
1	32·5° C. (90·5° F.)	37·0° C. (98·6° F.)
4	32·5° C. (90·5° F.)	38·8° C. (101·8° F.)
5	32·5° C. (90·5° F.)	37·8° C. (100·0° F.)

If all the cooled surface-water could be excluded there can be little doubt that the temperature in the subordinate eyes would also approximate to 41° C. In the passage-way itself below the water-logged mud of the vlei the temperature is doubtless considerably higher.

Geology.

Owing to the obscuring vlei there is no direct evidence to indicate the nature and origin of the passage-way up which the hot water rises. A large-scale plane table survey of the surroundings (p. 37), however, disclosed some significant facts.

Gneissic granite, which is definitely *in situ*, can be seen at many localities near the edge of the vlei, while a prominent N. 9° E.–S. 9° W. striking dyke of dolerite having an average width of 30 yards can be traced for several hundred yards both to the north and south of the vlei. The course of this dyke is somewhat sinuous and a few apophyses cut the granite. Furthermore, the dolerite has chilled margins, has epidotised the granite alongside it at certain localities, and where the contact is well-exposed the two rocks are fused together. It is thus certain that the dyke is a normal intrusion.

The presumed sub-outcrop of this dolerite dyke crosses the vlei only a hundred yards to the east of the spring in a direction parallel to the line joining the eyes. It would appear, therefore, that the hot water issues from a fissure in the old granite aligned parallel to the dyke, and to the injection of which it is probably related, since the dominant tectonic direction in the old granite itself is at this locality W. by S.–E. by N.

The Hot Spring dyke falls petrologically into the suite of dykes, probably of post-Karroo age, that are abundant in this part of the Low Veld.

Origin and Depth of the Spring Water.

Hot spring waters may be meteoric, juvenile, rejuvenated, or mixed in origin.

The Letaba Hot Spring presumably rises in jointed gneissic granite, and thus can be related to an artesian structure capable of returning heated meteoric water. However, the apparent constancy of temperature and flow and the degree of ionic concentration militate against an entirely meteoric origin.

Juvenile waters are emitted from cooling magmas which may be either deep-seated or injected into the crust at comparatively shallow depths.

In the eastern Transvaal, however, there is no evidence of any relatively recent volcanism to which the Letaba spring could be related.

Waters of mixed and doubtful origin rise from obscure deep circulations independent of seasonal rainfall variations. A part of such waters may be derived from cooling deep-seated magmas or the distillation and compaction of rocks, while either at depth or in ascent meteoric waters may be added.

Springs of meteoric origin which flow through granite contain, as a rule, CO_3'' as the dominant anion, SO_4'' and Cl' being very subordinate; the dominant cation is usually Ca''; Mg'' and Na' are subordinate, while K' is present in small amounts only. Silica is a major constituent in such waters. Inspection of the analytical results shows that the Letaba Hot Spring is not of this type, since it is dominantly a Cl' and Na' water.

Nevertheless in ascent a water can undergo changes in composition both by reaction and by deposition. As is well known, K' can replace metasomatically Na, and to a lesser extent Ca, in feldspars, while clays and certain base-exchange silicates take up preferentially K' and to a lesser extent Mg'', leaving much of the Na' and most of the Ca''. The operation of these processes may perhaps account for the ratio of Na : K in the Letaba Hot Spring water being 24·3 : 1, while the average of ten South African old granites (1) is about 1·1 : 1. Silica dissolved at depth may be deposited to some extent in ascent, as may be also calcium carbonate.

The granite, and to a lesser degree diabase and basic rocks such as amphibolite present in the granite, may well be the source of most of the ions present in the Letaba Hot Spring water. The Cl', however, is not so readily accounted for. Such Springs as Aliwal North, which have compositions very much like the Letaba Hot Spring, usually rise from sediments (the upper Beaufort in the case of the Aliwal North spring), and the sodium chloride which they contain was almost certainly derived in part from salts and connate waters therein. The presence of a large percentage of Cl' in springs rising from crystalline rocks has been taken by many authors to indicate a juvenile origin. Unless it be assumed that relatively large xenoliths of sedimentary rocks occur at depth in the granite below the Letaba Hot Spring, juvenile or rejuvenated water may therefore be contributing to the flow.

There remains, however, a distinct possibility that the Cl' may be derived from cyclic salts dissolved by meteoric water. The Indian Ocean is about 180 miles from the Letaba Hot Spring and during the summer months especially the prevailing winds blow from the S.E. In this connection it may be of significance that the ratio of Na : K in sea water,

27·5 : 1, is very close to that in the spring water. The fact, too, that in the spring water Na′ is in excess over Cl′ suggests that all the Cl′ was derived from NaCl. As compared with the proportions in sea water the spring water is very deficient in Mg″ but contains an excess of Ca″. Reaction with clays and base-exchange silicates, and the selective extraction, by leaching, of Ca″ from Ca-Mg silicates may explain this. However, if sea spray blown inland has in reality contributed to the salines, then it is rather surprising that the spring water does not contain any Br′, while I′, which in sea water occurs to only 0·000775 of the amount of Br′, should be present in relatively large amount.

Finally it is just possible that a part of the Cl′ may have been derived from connate salts in the Karroo strata of the Lebombo.

The determination of the isotope ratios of the K′ and other ions present in the Letaba water may, as in the case of the Saratoga spa, provide a clue.

More significant than Cl′ in denoting juvenile origin are BO_3''' and AsO_4''', but unfortunately these were not determined. Professor M. Rindl, who kindly checked the calculation and presentation of the analytical data to ensure accordance with the scheme formulated by the I.S.M.H., has pointed out to the writer the desirability of having a spectrographic analysis of the saline residue carried out when next the spring is investigated.

In the writer's opinion the Letaba Hot Spring ascends along the contact of the gneissic granite with the dyke, ultimately reaching the surface through an aligned fissure. The water exuded is in all probability mainly of meteoric origin, but the circulation is deep and inequalities in flow, composition, and temperature are smoothed out. Juvenile or rejuvenated water may be contributing to the flow. The composition and flow must also be affected to some extent by seepages from rain falling on the vlei and its surroundings.

The depth in the crust at which the hot water would be in thermal equilibrium with its environment can readily be calculated if the geothermic step is known.

In the Globe and Phoenix mine in Southern Rhodesia the geothermic step in the old granite is 214 feet per 1° C. (4), and at Dubbeldevlei, Cape Province, under a thick blanket of Karroo rocks, 150 feet per 1° C. (2). A figure of 200 feet per 1° C. is probably a fairly accurate approximation for the granite in the present area. If the mean winter surface ground-temperature is taken to be 20° C., then the spring originates at a depth of at least 4200 feet. This calculation, however, makes no allowances for the presence of rocks of different thermal conductivity, for loss of heat in ascent, or for possible contributions made by slow "porous plug" releases of pressure

or such chemical actions as the oxidation of pyrite or the kaolinisation of feldspars.

Although the spring water is only very slightly sulphuretted, oxidation of pyrite may be an important source of heat, since at depth pyrite would oxidise to iron sulphate. The Fe'' may be base-exchanged for say Na', leaving SO_4''. The small amount of H_2S now exuded may, however, be formed by the reduction of sulphates by organic matter introduced by influent seepage from the vlei.

Physical Properties of the Water.

The water is colourless, and practically odourless and tasteless when cold. On still days a faint odour of sulphuretted hydrogen may be detected in the open pool enclosure.

Conductivity, 1300 mhos (Govt. Chem. Lab., Johannesburg, on sample submitted April 1934).

Chemical Analyses of the Water, Etc.

(a) *Water.*—Two samples of water were collected by the writer on November 4, 1936, in Winchester glass-stoppered bottles which had each been thoroughly rinsed out twenty times with the spring water. These were analysed with the minimum of delay, and the results were communicated towards the end of December 1936. The original analyses were expressed in salines, but were later recalculated according to the recommendations of the International Society of Medical Hydrology.

In addition, the analyst tested for the following ions but with negative results: NH_4', Ba'', CO_3'', SH', SO_3'', S_2O_3'', PO_4''', free silicic acid.

A small amount of SH' may, however, be present since the samples unfortunately were not treated so as to fix any dissolved H_2S.

Ions.	No. 3 Eye.		Pool (Eyes 2, 3).		Aliwal North Spring.	
	Mgm. per litre.	N/1000.	Mgm. per litre.	N/1000.	Mgm. per litre.	N/1000.
Na' . . .	301·0	13·090	301·0	13·090	344·54	14·98
K' . . .	12·4	·318	12·4	·318	6·24	·16
Li' . . .	nil	..	nil	..	2·31	·33
Mg'' . .	1·4	·115	1·1	·090	5·52	·46
Ca'' . . .	30·1	1·505	29·1	1·450	83·80	4·19
Fe'' . . .	2·4	(·085)	1·7	(·061)	..	..
Al''' . . .	nd.	..	nd.	..	7·29	·81
Sum of cations.	347·3	15·028	345·3	14·948	449·70	20·93
Cl' . . .	445·0	12·550	446·8	12·600	605·27	17·05
Br' . . .	nil	..	nil	..	1·60	·02
I' . . .	2·0	·016	1·0	·008	..	..
SO_4'' . .	64·3	1·340	64·9	1·352	68·64	1·43
SiO_3'' . .	29·9	·786	28·3	·744	18·79	·49
CO_3'' . .	nil	..	nil	..	44·23	1·47
HCO_3' . .	17·1	·280	15·3	·251	29·43	·48
NO_3' . .	tr.	..	tr.	..	..	..
Sum of anions .	558·3	14·972	556·3	14·955	767·96	20·94
Total sum of ions	905·6	30·000	901·6	29·903	1217·66	41·87
SiO_2 . .	60·8	..	60·6	..	..	..
Grand Totals .	966·4	30·085	962·2	29·964	1217·66	41·87
pH at 25° C. .	7·9	..	7·8	..	..	..

Analyst: C. F. J. van der Walt, Division of Chemical Services.
Aliwal North Spring: P. D. Hahn (1 and 5).

The above analyses were expressed in terms of hypothetical salines, neglecting the trace of iodine in the Letaba water (first table, p. 44).

The analyst reports that the Fe is present as the colloidal hydroxide, and it has therefore been omitted from the sum of the cations.

Water collected from the pool in April 1934 was analysed by the Government Chemical Laboratory, Johannesburg, for the Malarial Research Department, Tzaneen, the result being as shown when recalculated according to I.S.M.H. specifications (second table, p. 44).

Salines.	No. 3 Eye.		Pool (Eyes 2, 3).		Aliwal North Spring.	
	Mgm. per litre.	N/1000.	Mgm. per litre.	N/1000.	Mgm. per litre.	N/1000.
$NaCl$ . .	733·5	12·547	736·4	12·597	846·19	14·46
$NaBr$ . .	nil	..	nil	..	2·06	·02
Na_2SiO_3 . .	28·6	·468	26·0	·426	30·16	·49
KCl . .	nil	..	nil	..	11·92	·16
K_2SiO_3 . .	24·5	·318	24·5	·318	nil	..
$LiCl$ . .	nil	..	nil	..	14·02	·33
$CaCl_2$ . .	nil	..	nil	..	116·29	2·09
$CaSO_4$ . .	91·1	1·338	91·8	1·349	42·16	·62
$CaCO_3$ . .	nil	..	nil	..	73·72	1·47
$Ca(HCO_3)_2$.	13·8	·170	12·2	·150	nil	..
$Mg(HCO_3)_2$.	8·0	·054	7·3	·050	33·58	·46
$(Fe, Al)_2O_3$.	3·4	..	2·4	..	..	..
$Al_2(SO_4)_3$. .	nil	..	nil	..	46·17	·41
SiO_2 . .	60·8	..	60·6	..	..	..
Totals .	963·7	14·895	961·2	14·890	1216·27	20·51

	Mgm. per litre.	N/1000.
Cl'	440·0	12·409
SO_4''	55·0	1·145
NO_3'	tr.	..
NO_2'	nil	..
Saline NH_3 . .	·080	..
Albuminoid NH_3 .	·085	..
O_2 absorbed (4 hours at 27° C.).	·400	..
Total hardness . .	80·0	Total Ca and Mg in v. d. Walt's analysis calculated as $CaCO_3 = 81$ mgm./litre, *i.e.* total hardness.
Permanent hardness .	35·0	Total Ca and Mg bicarbonates in v. d. Walt's analysis calculated as $CaCO_3 = 22·4$ mgm./litre, *i.e.* alkalinity.
Alkalinity (expressed as $CaCO_3$).	45·0	
Total solids . .	1040·0	..

Although this is only a partial analysis it shows that with respect to the dominant anions the spring has not altered appreciably in composition over a period of nearly three years.

(b) *Gas.*—Samples of gas were collected by Dr. Kupferbürger and the writer in the pool in July 1937. These were analysed with the following result:—

	A.	B.
O_2 . . .	21	20·5
CO_2 . . .	tr.	tr.
CH_4 . . .	nil	nil
H_2 . . .	nil	nil
N_2 (by difference) .	79	79·5
	100	100

Analyst: C. F. J. van der Walt.

It is at once apparent that the composition is almost identical with ordinary air. Unfortunately, however, a delay of several months ensued between the collection and the analysis of the gas, as at that time suitable apparatus for the analysis was not available in Pretoria. Some contamination may therefore have occurred. Nevertheless, the gases issuing from certain warm springs, such as the Ezulweni Spring (1) in Swaziland and Thundering Spring (8) in Georgia, U.S.A., have compositions agreeing very closely with that of the air. With regard to the composition of the gases emitted, the Letaba Hot Spring may be classed provisionally with these.

(c) *Mud.*—A sample of mud dug out of No. 4 eye was found after air-drying to contain the following water-soluble salts:—

Salines.	Per cent. of dried mud.
NaCl . .	·30
Na_2SO_4 . .	·36
$CaSO_4$ . .	1·00
$MgSO_4$ . .	·12
Total .	1·78

Analyst: C. F. J. van der Walt.

This mud may possibly have some therapeutic value as a peloid (3) of the vascular-vegetable terrestrial class, in which SO_4'' is the dominant ion.

Diatom frustules occur abundantly in the mud.

Classification.

(a) *Chemical.*—A slightly sulphuretted dilute chloride water, only barely more concentrated than the indifferent waters.

Total ionic concentration N/1000, 30·0.

Ionic concentrations of characteristic constituents N/1000,

Na 13·09 (Ca 1·5) Cl 12·6 (SO_4 1·4).

Following the method of presentation devised by Chase Palmer the water may be classified thus :—

	Letaba (average of the two analyses).		Aliwal North.	
	N/1000.	Per cent.	N/1000.	Per cent.
Primary Salinity	26·816	89·5	30·94	73·9
Secondary Salinity	1·050	3·5	6·06	14·5
Secondary Alkalinity	2·085	7·0	3·24	7·7
Tertiary Alkalinity	..	..	1·63	3·9
Totals	29·951	100·0	41·87	100·0

(b) *Physical.*—Hyperthermal. Radioactivity uncertain.

Several weeks elapsed between the collecting of the mud from eye 4 and its determination as non-radioactive by Mr. Immelman of the University of Pretoria.

Comparison with other South African Springs.

Approximately seventy thermal springs are known to occur in South Africa and over thirty in Southern Rhodesia. The waters of many of these, however, have not been analysed. Among those analysed the Aliwal North, Malmesbury, and Warmbad, South West Africa, springs have compositions approximating to that of the Letaba Hot Spring. As it is by far the better known, an analysis (1, 5) of the Aliwal North water has been added for comparison.

With regard to the Table Waters, the Letaba Hot Spring water resembles the well-known van Riebeck water (1).

Medicinal.

No clinical observations appear to have been made at this spring, and there is no provision for balnaeological treatments. Locally, however,

the spring is reputed to be efficacious in the treatment of rheumatism and various skin diseases.

During and after the Great War certain of the European hot springs, especially La Bourboule, Vichy, and Bath, were used as aids in the treatment of various tropical diseases and their sequelae which had affected troops who had served in the tropics (7). Medical research may prove certain of the South African springs to be equally beneficial.

Acknowledgments.

The writer is indebted to Mr. Devenish, the owner of the farm Eiland, and his manager Mr. de Klerk, for many courtesies extended during his visits. The 1934 analysis of the water was kindly furnished by Mr. Devenish.

The writer's thanks are also due to the Geological Survey drawing office for redrawing the map, and to Dr. Haughton for kindly communicating the paper.

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THE COMPARATIVE ANATOMY OF THE PROMONTORY REGION AND OF THE BONY COCHLEA IN MAMMALS.

(A Paper from the University of Cape Town.)

By J. A. Keen, F.R.C.S., Department of Anatomy.

(With Plates I–III.)

(Read May 21, 1941.)

From a comparative study of the tympanic bulla and auditory ossicles (Keen and Grobbelaar, 1941), it seemed a natural step to continue the anatomical investigation of the organ of hearing by studying the promontory region of the middle ear and the shape and size of the bony cochleae in a somewhat similar series of mammals to those used in the previous article.

Systematic studies of the inner ear fall into two groups: (1) The histological study of the cochlea after decalcification of the surrounding bone. The classical example of this is Retzius' great work Das Gehörorgan der Wirbelthiere (1884). The aim of such histological studies of the cochlea has been primarily to demonstrate the structure of the organ of Corti, but they are beset with difficulties especially in connection with the very perishable human material. These difficulties are so marked that most text-books of Histology rely on animal preparations to show the organ of Corti.

The mammalian species whose cochleae were described by Retzius with a great wealth of histological detail form a comparatively small group, viz. man, ox, rabbit, pig, and cat. Further histological preparations of mammalian cochleae which have been made by the Ferens Institute of Oto-Laryngology in London include sheep, calf, dog, guinea-pig, and mouse. Dr. Jean K. Weston (1939) investigated the comparative anatomy of the nerve cells in the spiral ganglion, and had at her disposal a large collection of histological preparations of cochleae in the Anatomical Institute of the University of Groningen. The collection comprises sections of the cochleae of 64 different animals, of which 12 are mammalian species. It is clear therefore that the cochleae of only a limited number of mammalian species have been examined histologically up to date.

(2) The second type of systematic study of the inner ear is represented by Gray's work on the membranous labyrinth, embodied in the two volumes of The Labyrinth of Animals (1907). The late Dr. A. A. Gray

approached the study of the inner ear by a special technique which resulted in the preparation of the membranous labyrinth. The temporal bones must be well preserved material. First a paraffin cast of the interior of the bony labyrinth is made by the injection of molten paraffin wax through the oval window. Then the block of petrous bone is decalcified in 5 per cent. nitric acid. When decalcification is complete the softened bony tissue can be brushed off the wax cast. The cast is then suspended in xylol after passing a fine thread through the loop of one of the semicircular canals. Gradually the paraffin is dissolved away and what remains is a preparation of the membranous labyrinth floating in xylol. Gray describes the membranous labyrinths of 75 different animals and gives the measurements; of this number 47 are mammalian species, the remainder including many species of birds and some reptiles and amphibians. Gray's list of animals therefore covers a larger number than the Groningen series. This very fine collection of membranous labyrinths is housed in the Museum of the Royal College of Surgeons. Unfortunately the preparations have not stood the test of time, and at present only a few specimens remain intact, the rest having broken up. However, the stereoscopic photographs in the two volumes of Gray's book remain as a permanent record of the appearances of the membranous labyrinths.

To these two methods of studying the cochlea I now propose to add a third method, which has not been described before and which approaches more closely to an anatomical and macroscopic dissection than those described above. The method is one of laying bare the successive turns of the cochlea by means of suitable apparatus for the piecemeal removal of the bony capsule. It is a simple process which can be applied to the dried petrous bones of animals, an immense advantage for several reasons. Many of the rarer animals in museums, and indeed extinct ones, are represented by their skulls. Classification in Zoology depends to a large extent on skull features, for the simple reason that this part of the skeleton persists longest. In this respect the teeth come first, but the petrous bones containing the pattern of the bony labyrinth are a good second. Shark's teeth and the cetolith of the whale are looked upon as the most resistant organic structures in the whole animal kingdom. They can be picked up from the bottom of the ocean long after the other parts of the skeleton have succumbed to the enormous pressures at that level. The cetolith of the whale is the portion of the petrous bone containing the bony labyrinth.

The Promontory Region of the Middle Ear (Pl. I).

Before beginning the dissection of the cochlea it is necessary to record the features on the inner wall of the tympanic cavity, because this bony

area is destroyed as soon as one begins to lay bare the first turn of the cochlea. The promontory region is seen after one has taken away the bony meatus, the tympanic ring, and the ossicles. It is the zone linking the tympanic cavity with the cochlea, and it therefore belongs partly to the middle and partly to the inner ear. In the dried bone the two windows are easily recognised (see Pl. I, figs. 1–12), the oval window above leading into the vestibule, the round window below leading into the scala tympani. It may be noted that the fenestra rotunda (f. cochleae) does not necessarily conform in shape to that implied by its name. In order to facilitate orientation, I have figured only right-sided petrous bones. The promontory is the bulge which sweeps downwards and anteriorly, *i.e.* to the right in the figures, and represents the first turn of the cochlea. When one sees an area of smooth bone around the promontory, this denotes the presence of a tympanic bulla (*e.g.* figs. 1, 3, 4, 10, and 12).

Attention may be called to certain special points in the different species. The part showing the promontory region of the whale (fig. 7) is the medial portion of the so-called cetolith, the lateral portion forming a modified, extremely thick-walled bulla. The two halves easily break apart, the line of union being the area of rough bone on the left side in the illustration. The solid stapes is still seen in the fenestra ovalis, as it is fixed there by bony ankylosis, a fact which has a considerable bearing on theories of sound transmission from the drum membrane to the cochlea (Keen and Grobbelaar, 1941). A deep groove running vertically in front of the promontory and curving anteriorly when above its level is the bony canal for the internal carotid artery, a feature characteristic of this region in all the Primates (fig. 9). In many Ungulates one finds a raised bony ridge between the oval and round windows. This is faintly indicated in the zebra (fig. 11), a little more marked in the giraffe (fig. 6), and it is a thick raised bar of bone in the elephant (not figured).

Macroscopic Dissection of the Cochlea.

By means of chiselling or sawing one separates the portion of the petrous bone which contains the labyrinth from the neighbouring bones, approaching the base of the skull from below. The bone immediately around the cochlea is always very hard and it was found impossible to use ordinary fine gouges and mallet, as the piece of bone was apt to break. The instruments required are of the dental drill type and circular emery stones driven by a small electric motor. Fortunately these were available in the Palaeontological Department of the South African Museum, where extremely hard fossil material is dealt with. The piece of petrous bone is held between the fingers and is pressed against the turning stone which

removes the bone. By using greater or less pressure and by increasing or decreasing the rate of rotation of the emery stone, one can control the drilling very satisfactorily.

It is useful to have at hand enlarged models of a right and a left labyrinth, as orientation is always difficult. At first one removes the bone over the promontory until the first cochlear turn becomes visible. The first turn of the cochlea near the round window may be a narrow canal, or it may show a considerable height in a vertical direction; the latter appearance is due to a downward bulge of the scala tympani characteristic of many mammalian species. On the inner wall of the first turn one always sees the shelf of the bony spiral lamina which partially subdivides the bony cochlea into two compartments, scala vestibuli above and scala tympani below. A piece of fine malleable wire, if introduced through the round window, appears in the scala tympani; and one through the oval window appears in the scala vestibuli. When the first part of the dissection is completed there is a danger that the scala tympani may become directly continuous with the opening of the round window, and thus one of the essential features of the promontory region can be easily destroyed.

Next one opens the second turn of the cochlea, then the apex; the continuity of the canal must be established from point to point by means of a fine wire. For the smaller specimens the use of a magnifying glass is essential. Gradually the whole bony cochlea is laid bare and one obtains a specimen in which one can count the number of turns of the cochlea, measure the dimensions of the organ directly, and study the anatomical disposition of the coiled tube.

There is one serious limitation to this method of direct dissection in that it is impracticable where the inner ear is very small. The bony cochleae of small mammals, such as mouse, other small rodents and insectivores, are such minute objects that one cannot deal with them in this manner. One of the smallest mammals in which I could do a macroscopic dissection of the cochlea was the cane-rat.

Construction of Models.

After completing a series of dissections, I constructed enlarged models of the different cochleae in order to display their anatomical features more clearly. I decided on a uniform 10 times enlargement, thus magnifying all the cochleae from a mm. to a cm. scale. In this way one obtains models which are clumsy as regards the large animals, but are easily handled objects in medium-sized and smaller mammals. The process involved making two drawings of the dissected cochleae, one showing it as a flat object and another showing the elevation with all the measurements

multiplied ten times. From these drawings plasticine models were made, and from the plasticine models permanent plaster of Paris ones by a double process of casting.

The orientation of the cochleae in relation to the petrous bones, and in relation to the planes of the skull, varies considerably from animal to animal. In order to make the models comparable it was necessary to fix on a definite plane in the cochlea as a uniform base, and I decided to consider the floor of the beginning of the first turn as the horizontal in each case and to build up the cochlea accordingly. In the human cochlea this "horizontal plane" is inclined downwards and forwards at an angle of about 30 degrees from the vertical. Illustrations of the models of the various cochleae are found on Pls. II and III.

TABLE I.

Measurements and Special Features of the Bony Cochleae.

(Measurements in millimetres.)

	Diameter of First Turn of Cochlea.	Diameter of Second Turn of Cochlea.	Width of First Turn near Round Window.	Height of Cochlea.	Index of Cochlea.	Type of Cochlea.	Number of Turns.
Homo sapiens	8·2	3·9	2·6	4·2	51	flat	2½
Baboon	6·2	3·0	1·9	2·8	45	flat	2½
Macaque	6·2	2·5	2·8	2·9	47	flat	2½
Cercopithecus sp.	5·7	2·3	1·8	3·0	53	flat	2½
Lemur: *Galago maholi*	4·0	1·4	2·0	2·8	70	intermediate	2¼
African Elephant	15·5	7·2	5·9	5·8	37	flat	2
Giraffe	10·0	4·0	3·6	5·6	56	intermediate	2½
Buffalo	12·5	4·8	4·5	6·4	51	flat	3
Zebra	11·0	4·1	4·0	6·2	56	intermediate	3
Rhinoceros	8·3	4·2	2·3	3·7	45	flat	1¾
Wildebeest	9·6	4·0	4·5	4·2	44	flat	2½
Duiker	7·4	2·1	2·9	3·4	46	flat	2¼
Springbok	6·6	2·5	3·0	3·7	56	intermediate	2½
Steenbok	6·9	2·7	2·7	4·1	59	intermediate	2½
Dassie: *Procavia capensis*	4·6	1·8	2·7	3·0	65	intermediate	2
Lion	8·2	3·3	3·6	6·3	77	pointed	3
Cat	6·9	3·1	3·0	4·0	58	intermediate	3
Dog	6·7	3·0	2·9	4·4	66	intermediate	3
Whale: *Pseudorca crassideus*	14·5	5·6	4·4	5·2	36	flat	2¼
Porpoise	8·6	3·5	2·5	3·6	42	flat	2
Kangaroo	7·4	2·5	2·7	4·7	63	intermediate	2¼
Porcupine	4·7	2·1	2·0	4·7	100	pointed	3½
Rabbit	5·0	2·0	2·2	2·5	50	flat	2¾
Cane-rat: *Thyronomis Swinderianus*	5·0	2·0	2·6	3·9	78	pointed	3
Guinea-pig	3·9	2·7	2·2	3·9	100	pointed	4
Shrew	3·2	1·7	1·0	2·4	75	pointed	2½

Discussion on Table I.—Gray divides cochleae into two types: flat cochleae and pointed cochleae. It is convenient to introduce an "intermediate" group between the flat and pointed cochleae. The different orders of the mammals keep fairly constantly to their particular type. The diameter of the first turn is a measurement taken straight across the cochleae from a point below the round window to a point opposite. The diameter of the second turn is a measurement across the second turn in a direction parallel to the diameter of the first turn. The width of the first turn is a transverse measurement just below the round window. The "height" of the cochlea is the distance between the "horizontal plane," as defined previously, and the apex of the cochlea.

In order to make these measurements quite clear I have indicated them by interrupted lines in fig. 24 (Pl. II) and fig. 29 (Pl. III). A–B is the diameter of the first turn; C–D is the diameter of the second turn; E–F is the width of the first turn; G–H (fig. 29) is the height of the cochlea.

The relation between the diameter of the first turn and the "height" determines whether the cochlea is flat, intermediate, or pointed. On the one hand, we have cochleae where the diameter of the first turn is nearly twice as much as the height; these are the flat cochleae. On the other hand, cochleae where the two measurements become equal or nearly so. These are the pointed cochleae, with the intermediate type between the two extreme groups.

On analogy with the procedure adopted in Physical Anthropology to express differences in shape of various anatomical units, I have added a column for a cochlear index to the table of measurements. This index gives a numerical expression to the shapes of the cochleae in the various species examined, by establishing the relationship between the height of the cochlea and the width at the base. Thus index of cochleae $= \frac{\text{height of cochlea} \times 100}{\text{diameter of first turn}}$. Animals with a low index figure have flat cochleae, those with a high index have pointed ones, and there is an intermediate group. Cochleae with an index of 55 – I have called "flat," those with indices of 75 + I have called "pointed," and those with an index between 56 and 74 "intermediate." The index of the cochlea is the figure which is characteristic for each mammalian species. Having in mind very similar terms in Physical Anthropology, I suggest the adjectives *chamaecochlear*, *mesocochlear*, and *hypsicochlear* to designate mammals with flat, intermediate, and pointed cochleae respectively.

The first turn of the cochlea in the region of the round window often shows a remarkable depth due to a bulging of the scala tympani in a downward direction. Gray noticed the downward bulging of the scala tympani in the lion, cat, dog, rabbit, and kangaroo. My dissections confirm Gray's observations; a bulging was further noted in the buffalo,

wildebeest, steenbok, springbok, cane-rat, and porcupine (see Pl. III, figs. 27, 28, and 31). In others there is no bulging, *i.e.* the scala tympani and scala vestibuli have much the same depth, and the spiral lamina is seen midway between the two canals. Instances with no bulging in my series are the cochleae of man, baboon, macaque, a species of cercopithecus (fig. 25), whale, porpoise, giraffe (fig. 32), elephant, rhinoceros. A slight bulging of the scala tympani is seen in the dassie (fig. 26), lemur, duiker, zebra, and the guinea-pig (fig. 30).

The downward bulge of the scala tympani lowers the "horizontal level" and alters the orientation of the cochlea. For instance, if my definition of the horizontal level be not accepted and the bulging be considered a projection below the general level of the first turn, then many of the intermediate cochleae in Table I would have to be called flat ones. A good example of a deep first turn is the lion's cochlea (fig. 31). The first turn near the round window is so deep that it reaches almost to the apex and suggests a flat cochlea. However, the relation between the diameter of the first turn and the height places this cochlea in the intermediate group.

Gray states that the Cetacea, whale, and porpoise have very similar cochleae, except for size (vol. ii, p. 26). The models of the whale's cochlea (fig. 21) and that of the porpoise confirm Gray's observation. The giraffe's cochlea shows a curious upward tilt of the distal half of the first turn,

TABLE II.

Comparison of Measurements.

(Millimetres.)

	Diameter of First Turn.		Diameter of Second Turn.		Width of First Turn near Round Window.	
	Gray.	Own.	Gray.	Own.	Gray.	Own.
Homo sapiens . .	8·2	8·2	4·6	3·9	2·0	2·6
Baboon . . .	6·0	6·2	3·0	3·0	1·5	1·9
Cercopithecus sp. .	5·2	5·7	2·5	2·3	1·5	1·8
Lemur . . .	5·0	4·0	3·0	1·4	2·0	2·0
Lion. . . .	9·0	8·2	6·0	3·3	. .	3·6
Cat	6·0	6·9	3·5	3·1	2·5	3·0
Dog	6·2	6·7	3·5	3·0	3·0	2·9
Whale . . .	20·5	14·5	12·5	5·6	4·5	4·4
Porpoise . . .	8·5	8·6	4·5	3·5	3·0	2·5
Kangaroo . . .	6·0	7·4	3·5	2·5	3·5	2·7
Rabbit . . .	3·0	5·0	2·0	2·0	1·7	2·2

which brings this part of the first turn actually above the level of the apex (fig. 32). The guinea-pig has a pointed cochlea with a remarkable sideways inclination (fig. 30).

Discussion on Table II.—As I have pointed out elsewhere, the outside dimensions of the scala media in the cochlea are practically identical with the dimensions of the bony cochlea, because the spirally coiled scala media lies against the outer endosteum of the spiral bony canal (Keen, 1939). Therefore it is of considerable interest to compare Gray's measurements and my own in those animals which figure in both Gray's "Labyrinth of Animals" and in the present series.

The measurements do not always agree, one reason being that the animals whose cochleae were studied belonged to different species. Gray does not state how the diameter of the first turn is measured. Whether he has taken the maximum possible distance, *i.e.* from a point between the oval and round windows to a point opposite, or in a straight line across the cochlea; neither does he explain the diameter of the second turn. Also one imagines that the measurements of such a delicate object as the membranous labyrinth floating in fluid had to be taken from the outside of the glass container with resulting inaccuracies.

Further, it may happen that the membranous labyrinth when released from its bony capsule undergoes a certain amount of distortion; or perhaps there is a certain amount of inherent elasticity which might cause the coiling of the cochlear canal to become exaggerated. This almost certainly occurred with the membranous labyrinth of the baboon which Gray describes as such a specially beautiful object (vol. i, p. 39). He states that the baboon's inner ear is more pointed than that of other primates, possessing 3¼ turns against 2½ of the other primate cochleae which were examined. In my series the bony cochlea of the baboon closely resembles that belonging to a species of cercopithecus and of the macaque, each with 2½ turns, and I was not able to discover those special features.

The differences in the lemur measurements are probably due to a difference in the species examined. The membranous labyrinth in Gray's series came from a Mongoose Lemur, my specimen came from the skull of a smaller African lemur, *Galago maholi*. The same applies to the whale. The species examined by Gray was *Balaena australis*. The cetolith from which I dissected the cochlea was that of *Pseudorca crassideus*, the smaller toothed whale. These are widely different species of the Cetacea and represent the two great suborders of the whales.

It may be suggested that the age factor should be considered in comparing measurements, *i.e.* whether the cochlea came from a young animal or a full-grown one. This factor does not apply as regards the cochlea. Many years ago it was proved for man that the middle ear

structures and the inner ear remain the same size throughout life from birth onwards (Kikuchi, 1903; Feldman, 1920). There is no reason to believe that conditions are different in other mammals.

The comparative anatomy of the cochlea emphasises the great importance of the sense of hearing. There is no doubt that in many animals the sense of hearing takes precedence over the sense of vision. We know of mammalian species where the eyes are rudimentary and the visual centres hardly developed owing to their adaptation to a darkened world (*e.g.* moles). But I know of no mammal that has a deficient cochlea or defective auditory centres in the brain. It would appear from the series of cochleae I have described that all mammals require a well-developed coiled cochlea for the reception of sound impulses.

Summary.

After discussing the various methods of studying the cochlea and reviewing the literature, the author describes a method of exposing the bony cochlea which can be applied to the petrous bones obtained from dried skulls. Enlarged models of the cochleae can be made and a selection of such models are illustrated both as flat objects and in elevation. The comparative anatomy of the promontory region of the middle ear and of the cochlea is discussed, and two tables of measurements give the dimensions of the bony cochlea in twenty-six mammalian species.

I am greatly indebted to Dr. E. L. Gill for allowing me to use material obtained from a collection of mammalian skulls at the S.A. Museum, Cape Town, and to Dr. L. D. Boonstra for permission to use instruments and apparatus in the Palaeontological Department of the S.A. Museum. I also gratefully acknowledge the help from a research grant of the University of Cape Town towards the cost of preparing the illustrations.

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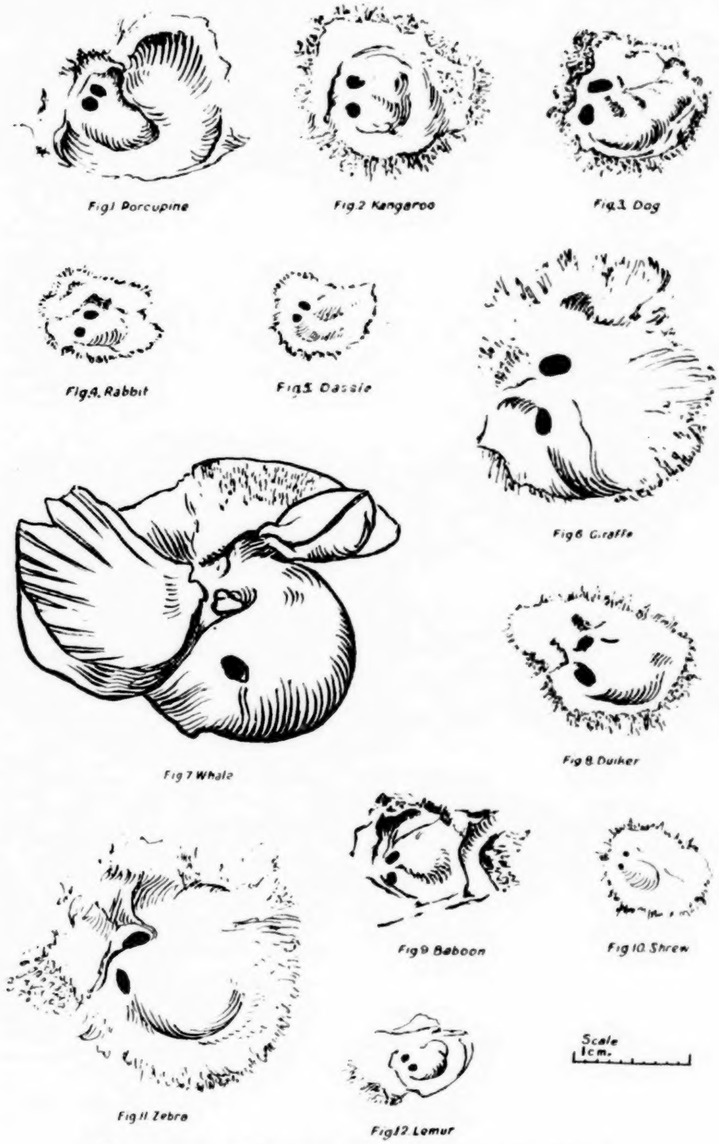

The Promontory Region of the middle ear in various mammals.

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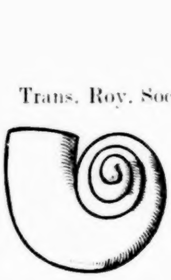
Fig. 13 Porcupine


Fig. 14 Shrew


Fig. 15 Dassie

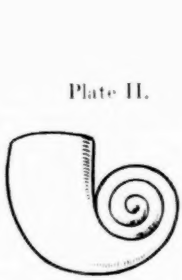
Fig. 16 Cane-rat


Fig. 17 Cercopithecus sp.


Fig. 18 Springbok


Fig. 19 Cat

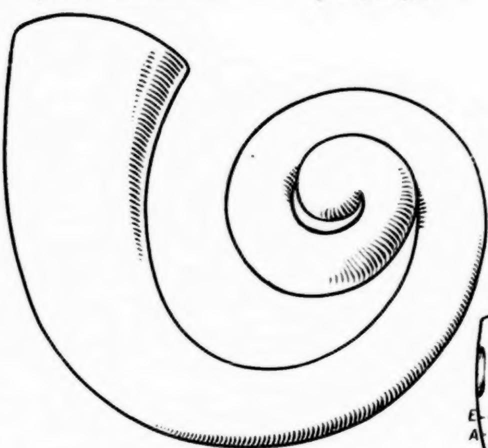
Fig. 21 Whale


Fig. 20 Kangaroo

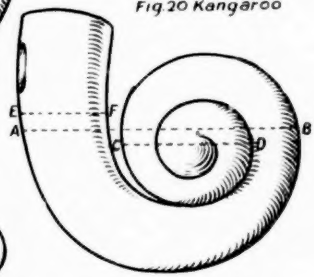

Fig. 24 Human

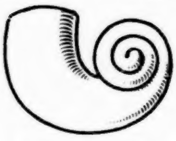
Fig. 22 Rabbit


Fig. 23 Lemur

Drawings of models of the bony cochleae in various mammals.

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Fig. 25 Cercopitheeus sp.

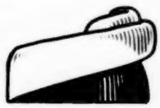

Fig. 26 Dassie

Fig. 27 Cane-rat

Fig. 28 Porcupine

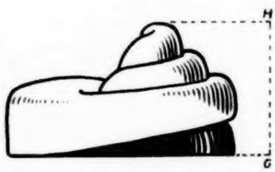

Fig. 29 Cat

Fig. 30 Guinea Pig

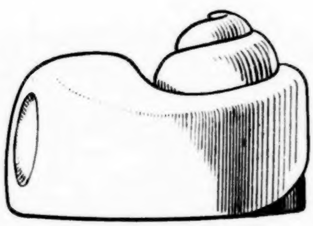

Fig. 31 Lion

Fig. 32 Giraffe

Drawings of models of the bony cochleae in various mammals to show the elevation.

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FOSSIL FLORA OF THE WITTEBERG SERIES.

By J. V. L. Rennie and E. D. Mountain.

(Read May 21, 1941.)

From time to time plants have been described as from the Witteberg Series and it has become customary to refer to a Witteberg flora. Until comparatively recently only some very poorly preserved plant-remains have been recognised as occurring in the underlying Bokkeveld Series, the lower part of which contains the well-known lower Devonian marine fauna. From the Bokkeveld Series, and more particularly from the upper part, plants have now been recorded, and these appear to be Psilophytalean and of Devonian age. Hoeg (1930) has described a new genus *Dutoitia* from the Bokkeveld Series near Knysna, and Seward (1932), in describing plants collected by Haughton (1935) from the upper part of the Bokkeveld Series near Steytlerville, has erected the genus *Haplostigma*, applying the specific name *H. irregulare* (Schwarz) to Bokkeveld as well as Witteberg material. Similar plants have been figured from elsewhere in the Bokkeveld Series: one from the neighbourhood of Matroosberg Station (formerly known as Triangle) (see Seward, 1903, p. 92, pl. xi, fig. 4, locality and horizon correctly given in the erratum note at the beginning of the volume); another from the Uitenhage division (Seward, 1932, p. 362, pl. xxiii, fig. 7).

Haughton (1935, p. 12) has pointed out that, at Steytlerville, the upper beds of the Bokkeveld Series belong to a non-marine facies, which, palaeontologically, is closely allied to the Witteberg Series.

The mapping of the district surrounding Port Alfred has now revealed that certain fossiliferous horizons hitherto regarded as of Witteberg age are below the massive quartzites of that series, and if the usual lithological division is accepted, much of the so-called Witteberg flora falls within the Bokkeveld Series, as well as the few animal remains formerly referred to the Witteberg Series.

The "*Bothrodendron*" *irregulare* material described by Seward (1909), as well as the supposed eurypterid fragments named *Hastimima* (Seward, 1909; Woodward, 1909), comes from the Mental Hospital at Port Alfred, occurring in shaly rocks presumably near the top of the Bokkeveld Series.

The series of rocks tilted up on end at the railway-station quarries at Port Alfred consists of shales and sandstones with only occasional thin bands that might be described as quartzitic. They are separated from the nearest outcrop of Witteberg rocks by at least half a mile, but the intervening space is largely occupied by river alluvium in the Kowie river valley. Owing, moreover, to the considerable disturbance that the rocks of the Cape System have here undergone, it is not possible to define the exact horizon of these rocks, but it nevertheless seems probable that they are well below the top of the Bokkeveld Series and at the same time they possess a lithological character typical of that series. To the Bokkeveld Series, then, must be assigned some of the type material of "*Lepidodendron*" *kowiense* Schwarz (1906, Albany Museum nos. 157, 167, 172)., The holotype of this species (no. 143), despite its name, is from the Cold Bokkeveld, and the exact horizon is unknown, but the matrix is a shale and it is by no means certain that it is a Witteberg specimen. On the other hand, some of the type material is from the Witteberg quartzites, certainly Albany Museum nos. 169 and 2130, both from the neighbourhood of Grahamstown, and possibly also nos. 2615 and 2616 from Boschluis Kloof.

The imposing list of lycopod generic names mentioned long ago by Grey (1871), and quoted subsequently by Feistmantel (1889) and others, was based on material from micaceous shales at Port Alfred, presumably Psilophytalean, and probably Bokkeveld in age.

The *Palaeestheria* recorded by Rennie (1934) is from the railway-station quarries at Port Alfred and therefore from the Bokkeveld Series. The only other animal fossil recorded from the district consists of some poorly preserved specimens (Albany Museum nos. 38 and 39) which are either patelliform gastropods or brachiopods of the *Orbiculoidea* type. They were mentioned by Reed (1925) as having been erroneously identified with *Metoptoma capense*. They come from Rokeby Park, on the main road between Grahamstown and Port Alfred, which is situated well within the limits of the Bokkeveld Series.

The type of "*Bothrodendron*" *irregulare* Schwarz (1906) is in carbonaceous shale resembling that of the Port Alfred railway-station quarries and comes from "Estment's Farm, Kowie." The designation of this locality is somewhat misleading, for the farm is situated only 3 miles E. of Bathurst railway station, on the Kleinemond Road, and is now known as Sweet Fountain. The occurrence is at the head of the kloof to the west of the homestead. Here the black shales are seen to dip southwards at 15° and lie about 100 feet below the base of the Witteberg Series, which crops out 120 yards farther south as a conspicuous band of quartzites. These shales were excavated several decades ago in an unsuccessful attempt to obtain coal.

The ?*Archaeopteris* leaves recorded by Schwarz (1906) were said to come from micaceous shales underlying the Witteberg quartzites.

The type of *Bothrodendron caespitosum* Schwarz (1906) is a ferruginous cast recalling the condition of many Bokkeveld marine fossils. It is from the Cold Bokkeveld, horizon unknown.

The holotype and paratype of *Lepidodendron albanense* Schwarz (1906) from the neighbourhood of Grahamstown are undoubtedly from the Witteberg Series, and the holotype of *Didymophyllum expansum* Schwarz (1906) from Steytlerville is in quartzite and presumably also from the Witteberg Series.

Mention might finally be made of the problematical fucoid-like impression *Spirophyton*, which has been described as occurring widely in the Witteberg Series of the western Cape Province. Seward was firmly convinced that it was not of vegetable origin, and it now appears to be accepted as due to a burrowing worm. It has already been described as occurring in the Bokkeveld Series near Steytlerville, by Haughton (1935, p. 12); and just south of Grahamstown, both at Howieson's Poort and on Woest Hill, good specimens have been found in the same series about 100 feet from the top.

The condition of much of the fossil material concerned does not at present admit of a definite distinction between the plants of the upper part of the Bokkeveld Series and those from the Witteberg quartzites. While the bulk of the Psilophytalean remains now appear to be from the Bokkeveld Series, a few "Bothrodendroid" specimens of the *Haplostigma irregulare* type have come from the succeeding Witteberg. On the other hand, "Lepidodendroid" remains, similar to *L. albanense*, appear to be confined to the Witteberg Series, the "*L.*" *kowiense* type material being most probably identical with *H. irregulare*, as Seward (1909) has suggested, and not really "Lepidodendroid" in character.

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OBSERVATIONS ON THE RELATION BETWEEN NUCLEOLUS AND CHROMOSOMES IN SALIVARY GLAND NUCLEI OF SOME SOUTH AFRICAN DROSOPHILIDS.

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(Communicated by Professor C. J. van der Horst.)

(With Plates IV and V, and eight Text-figures.)

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Up to the present the direction of cytological research has been mainly determined by the demands of genetics, with the result that progress has been made chiefly in connection with the structure and behaviour of chromosomes. A very successful period was registered, while the recent modes of attack are even more promising. The cytogenetic nature of taxonomic differences is one example of a promising field, developmental genetics is another, while biochemical analysis and interpretation have been started. Our concept of the gene is being gradually moulded. Once more, as a result of our knowledge of chromosomal rearrangements and position effects, attention has been focused on the chromosome as a whole.

In the meantime the study of such bodies as the centriole in animal cells, the spindle, and the nucleolus has been left to relatively few and isolated workers. Here and there workers expressed their opinion as to the possible functions of the nucleolus, but the ideas were conflicting. The result has been that textbooks on cytology and genetics create the impression that the nucleolus is merely a by-product of no genetic importance.

Recently, however, the nucleolus has received special attention, and renewed interest in its origin, life-history, and possible functions is spreading. This revived interest must in the first place be attributed to observations on the production of nucleoli by organisers associated with secondary constrictions in SAT-chromosomes and to observations on the position of the nucleolus in salivary gland nuclear constellations of Diptera.

However, because of the fact that the nucleolus, as a rule, breaks up and gradually disappears as the nucleus begins to divide and is recon-

stituted at the beginning of the next resting stage, the idea is still generally held that the nucleolus has no genetic significance. On the other hand, there are some like Geitler (1934) who are convinced that the nucleolus cannot be looked upon merely as a by-product, although Geitler does not think that the nucleolus takes any part in cell-division or chromosome building. But there are others who are of the opinion that the data warrant a reconsideration of the older theory, that the chromosomes do get "nourishment" from the nucleolus. The author wants to associate himself, although in a slightly modified manner, with this last group.

Fikry (1930) refers to observations by Schurhoff, Beer and others, emphasising that while the nucleolus gradually decreases in size and staining capacity during cell division, the chromosomes increase in size and staining capacity. It seems as if these latter processes take place at the expense of the former. It appears that the nucleolus in *Equisetum arvense* is actively "secreting" material in the form of droplets or small buds from its surface. At the same time the chromosomes grow in thickness and their staining capacity increases. The droplets actually pass into the nuclear space and are distributed along the chromosomes, to which they remain attached.

But there is also supporting evidence from observations on the mode of attachment of chromosomes to nucleoli, especially during prophase. Coonen (1939), for instance, observed in *Ranunculus* species that when the chromonemata are contracting to more deeply staining chromosomes during middle and late prophase, the satellites, setae, and proximal ends of the chromosomes are lying on the surface of the nucleolus.

Geitler (1934) states that in the case of several *Spirogyra* species the chromosomes are carefully coated with the nucleolar material. In the case of *Spirogyra setiformis* the nucleolar substance gets pulverised during prophase, after which the chromosomes penetrate into it. The nucleolar substance then divides into two elongated masses containing the longitudinally split chromosomes which now move, within the nucleolar masses, to the poles. Furthermore, the nucleolar material disappears with the increase in thickness of the chromosomes. During anaphase the nucleolar substance goes over on the chromosomes, which as a result immediately increase in thickness. This, however, only leads Geitler to state that: "so sind doch anderseits nicht alle Nukleolen gleichartig."

Recent researches indicate that the chromonemes, as threads carrying the genoplasma, are surrounded by a matrix called kalymmatin (Heitz, 1935). Furthermore, chemical studies such as those of Marshak (1931) indicate a great chemical resemblance between nucleolar material and kalymmatin. Fikry (1930) considers the nucleolar material as an enzymatic substance.

These facts and considerations have given rise to the revived theory of the function of the nucleolus. It states that the genes can select during prophase what they need from the kalymmatin on the basis of their selective powers as colloidal substances. During telophase some of this ground substance is again "secreted," by SAT-chromosomes as nucleolar bodies which might during the resting phase flow together as one large nucleolus with which prophase commences.

It is then chiefly the study of the nucleolus during prophase that must show whether this body is concerned with chromosome building or not. The salivary gland nuclei of Diptera are of great importance in this connection. These nuclei are really in a continuous prophase and, as far as younger larvae are concerned, in active prophase of endomitosis—if that term be allowed to connotate the special type of division of the chromosomes in the salivary gland nuclei of these young larvae.

The observations on the salivary gland nuclei of *Drosophila* show without doubt that the nucleolus is always connected either directly or indirectly to the chromosomes. The study of the nature of this connection is of the greatest importance. If during prophase the connection is such that transfer of material is possible, then it certainly suggests that the nucleolus supplies the chromosomes with building material.

Frolova, who has given special attention to the position taken up by the nucleolus, considers this connection between nucleolus and chromocentre to be a thread or several threads. This connecting mechanism will be considered here.

The classical salivary gland nuclear constellation in *Drosophila* is that of *Drosophila funebris* Fabricius worked out by Frolova (1936). Fig. 1 shows five long elements and one small element (*m*) connected to the central mass (*ch*) from where a spiral thread leads to the nucleolus (*n*). The elements do not abut directly on to this central mass or chromocentre, but from each element threads lead to it (continuation of genonemata?). The chromocentre is formed during telophase as a result of the fusion of the proximal parts of the chromosomes. In the V-shaped chromosomes the proximal parts are on either side of the primary constriction, where the spindle-fibre is attached in the case of chromosomes in meiosis or mitosis. In the case of the rod-shaped chromosomes (usually the X-chromosome) the proximal part is at the one extreme end of this element. These proximal or inert parts do not agree with the remaining part of the chromosome, which contains the conspicuous bands or rows of chromomeres. The proximal ends differ also in staining reaction. The composition of the proximal parts is called heterochromatin and the remaining part euchromatin. In the early larval stage the homologous chromosomes are separate and composed of two closely connected threads or genonemata.

The homologous chromosomes become synapsed, the corresponding chromomeres are doubled accordingly, and create the appearance of transverse bands. After this, two or more divisions of the chromonemata take place without the cytoplasm dividing (Chromonemata = genonemata with chromomeres and chromoplasma).

The formation of the thread connecting the chromocentre with the nucleolus is still largely unsolved. According to Frolova (1938) it is

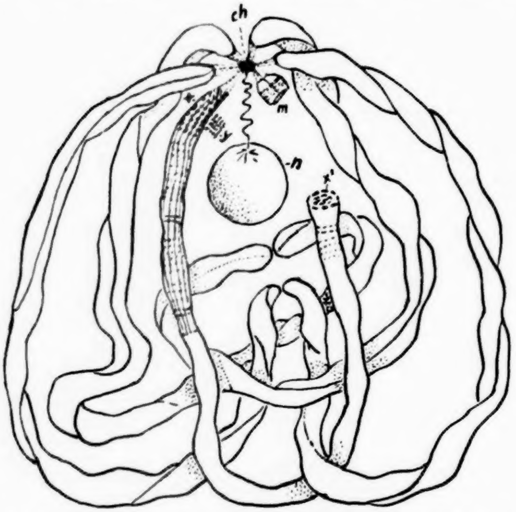


Fig. 1.—Plan of the nuclear constellation from salivary glands of *Drosophila funebris*. After Frolova.

formed during the transition from telophase to the resting nucleus. Observations on *Drosophila robusta* led Frolova (1936) to conclude that this thread is the result of the junction of remnants of fibres of the half-spindle of the previous telophase. They are attached to the so-called Leitkörperchen of the heterochromatic parts of all chromosomes. As these parts fuse to form the chromocentre this latter will show the Leitkörperchen containing the half-spindle fibres. How these fibres join and become attached to the nucleolus is not clear, although it is stated that drops of heterochromatin may run along these fibres to the nucleolus. However, in 1938 Frolova only states that this thread is formed during transition from telophase to resting nucleus and that its nature is so far not clear.

Frolova does not suggest that the observations made on *Drosophila robusta* should be transferred to other *Drosophila* species. But it is an

important assertion that drops may flow along this connection to the nucleolus. It imparts to the latter body a recipient function. But then only the drops and not their movement were observed. The movement of drops could just as well have been from the nucleolus to the chromocentre.

In the following paragraphs it is the intention to show that this connection between chromosomes and nucleolus is either of a tubular or a bridge nature, making possible a communication either indirectly *via* the chromocentre or by direct contact with the chromosomes themselves. Afterwards the meaning of such a communication will be considered.

Observations on the salivary glands of some South African Drosophilids and other Diptera yielded interesting data in this connection.

Specimens of *Drosophila busckii* were collected during 1939 on the University grounds by exposing bottles containing overripe fruit. Cultures were easily made, and this species proved to be of a hardy nature.

Most of the observations and drawings were made from temporary slides prepared as follows:—

A large well-fed larva which is about to pupate is transferred to a drop of Ringer's solution on a clean slide. With the aid of a dissecting microscope and eye-dissecting needles the brain and salivary glands are removed from the anterior portion of the larva and transferred for 10–20 minutes to a slide containing a few drops of 45 per cent. acetocarmine solution. Spreading is best done by gently making circular movements with the surface of the finger-nail over a piece of filter paper placed on the coverslip, excess stain being removed at the same time. After the desired spreading is obtained, the edges of the coverslip are insulated by a thin layer of vaseline. The slide may keep for two weeks.

Permanent slides may be obtained by transferring the slides either directly to 96 per cent. alcohol for 15–30 minutes, or first to a 96 per cent. vapour bath for 12–24 hours and thereafter to 96 per cent. alcohol until the latter has penetrated into the tissues and the coverslip loosened. This may occur within 30 minutes. The slide and coverslip are removed from the alcohol, euparal is dropped on the tissues, and the coverslip placed on the slide in its original position.

A temporary slide may be made into a permanent one by removing the vaseline insulation and proceeding as above.

For the observations discussed below, the following lenses were used: Zeiss objectives 90× and 40×; Leitz objective 114×; Bausch & Lomb 120×; Zeiss eyepiece 10×; and Leitz eyepiece 6×. Drawings were made either with a Zeiss drawing prism, together with a Zeiss eyepiece 10× or with a Leitz drawing eyepiece 6×.

Metaphase cells from the supra-oesophageal ganglion of larvae and

oogonia of imagines of *Drosophila busckii* show the presence of only three pairs of chromosomes, including two large V-shaped chromosomes and a pair of rodlike chromosomes which probably are the X-chromosomes. These are shown in fig. 2, drawn from a female larva.

Observations on salivary gland nuclei of this species showed a relatively simple constellation (Pl. IV (*a*), involving four separate elements labelled 1, 2, 3, and 4 in fig. 3. The elements are as follows: two large chromosomes of approximately the same length and each one showing a distinct constriction dividing the chromosome into unequal halves. One of these large chromosomes (No. 2) can be readily distinguished from the other large one by the presence of a heavy swelling approximately about a quarter of the distance from the free end of the shorter arm. This swelling can sometimes be very pronounced and almost nucleolus-like in being relatively free from bands. These large chromosomes are taken to represent the V-shaped chromosomes in the ganglion cells.

FIG. 2. — Metaphase chromosomes from supra-oesophageal ganglion cells of *Drosophila busckii* larvae. ×4860.

Of the two remaining chromosomes the one is approximately half the length of a V-shaped chromosome of the same constellation and is

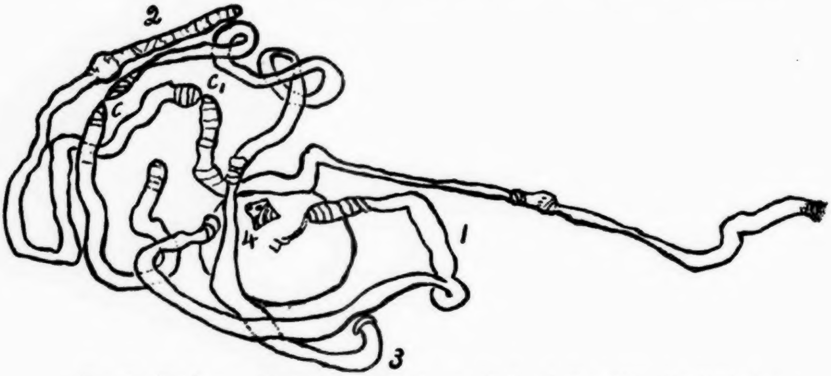
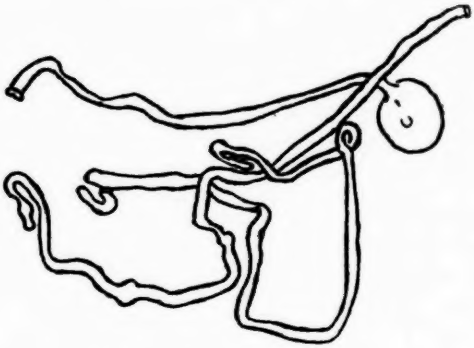


FIG. 3.—Nuclear constellation from salivary glands of *Drosophila busckii* larvae showing four separate elements, Nos. 1 and 4 communicating directly with the nucleolus. ×815.

taken to represent the rodlike chromosomes of the ganglion cells, *i.e.* the X-chromosomes.

The last chromosome to be mentioned is a very small rhomboid body showing indefinite striations and not more than $\frac{1}{20}$th the length of what are considered the X-chromosomes. Its nature is not quite clear.

The arrangement of the chromosomes with reference to the nucleolus is interesting. No chromocentre has been observed and the constrictions C and C_1 of the V-shaped chromosomes show neither "Leitkörperchen" nor threads, but the end of one of the larger arms of the large chromosome (labelled 2 in fig. 3) shows what may be considered a heterochromatic end. It is interesting that the X-chromosome and the smallest element (labelled 4) communicate directly with the nucleolus. The smallest element



FIGS. 4, 5.—Nucleoli from salivary gland nuclei of *Drosophila busckii* larvae showing chromosome 1, communicating directly with the nucleoli. $\times 600$ and $\times 815$ resp.

lies flush against the nucleolus, while the end of the X-chromosome seems to penetrate right into it. Figs. 3, 4, and 5 show typical connections. The chromosome narrows slightly, just before entering the nucleolus, in a circular manner much as a tapering tube would do. Near this circular entrance stress lines and vacuoles may be seen. The threads which are seen are undoubtedly the continuation of the genonemata. The tubular entrance is seen distinctly in a photograph (Pl. IV (*b*)). In fig. 4 the entrance is more abrupt, no tapering of the chromosome occurring. In fig. 5 the end of the chromosome tapers slightly and merges into a fanlike stream showing a few small vacuoles.

It is of course quite possible that the two large chromosomes communicate normally with the nucleolus, but their attachment is probably

easily disturbed because of the size of these chromosomes. Under pressure of the coverslip they have a greater chance of being separated from the nucleolus than in the case of the smaller chromosomes.

The well-defined constrictions C and C_1 (fig. 3) do not suggest that the attachment, if occurring naturally, would be in the usual manner. It suggests an end attachment which will account for the irregular end of chromosome 2. Further investigations are being carried out to get more light on the mode of attachment of chromosomes 2 and 3 and to attempt to explain the fairly constant association of No. 4 with No. 1.

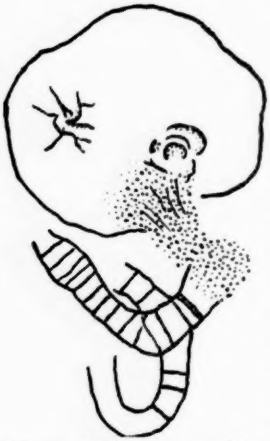


FIG. 6.—Nucleolar connections in salivary gland nuclei of *Drosophila immigrans* larvae. × 1350.

Observations on salivary gland nuceli of *Drosophila immigrans* Sturt. revealed that a distinct stream or mass of heterochromatin here connects chromocentre with nucleolus, and at its junction with the nucleolus circular marks may be seen (fig. 6). Again, threads (genonemata) may be seen in this stream.

Drosophila immigrans Sturt. with its relatively large salivary gland nuclear constellations is admirably suited for class-work. Of all the different species kept in the Department of Zoology of the Witwatersrand, the salivary gland chromosomes of this species stain most easily, and the relatively unstained cytoplasm allows for successful photography and observation generally. The very large salivary glands are easily dissected out. The species is furthermore easily identified by its large size, yellowish brown colour, cloudy posterior cross-vein, its large larvae with darkly chitinised posterior spiracles usually pointing upwards when feeding, and large pupae with long spiracles having subdivided ends. The species is widespread in South Africa and easily bred. It is recommended for beginners of this special branch of cytology in South Africa.

Also, in *Drosophila funebris* (fig. 7) a connection which is very reminiscent of a thin tube with trumpet-like ends is seen. Frolova (1936, 1938) gives figures which do not exclude the possibility of a tubular heterochromatic form of the connection between chromocentre and nucleolus, *e.g.* those of *Drosophila funebris* and *Drosophila robusta*. If Frolova's thread or multiple thread be considered as derived from the heterochromatic part of the chromosomes containing continuations of genonemata instead of considering it derived from half-spindle remnants, as, for instance, is suggested by observations on *Drosophila robusta*, then also her constella-

tions may be considered as additional evidence of a tubular or at least a kalymmatic connection, *i.e.* ground substance connection.

The genus, *Zaprionus*, offers another example of direct chromosomal connection with the nucleolus.

Specimens collected on the Rand and at Rustenburg were identified and separated into *Zaprionus tuberculatus* and *Zaprionus vittiger* I and II.

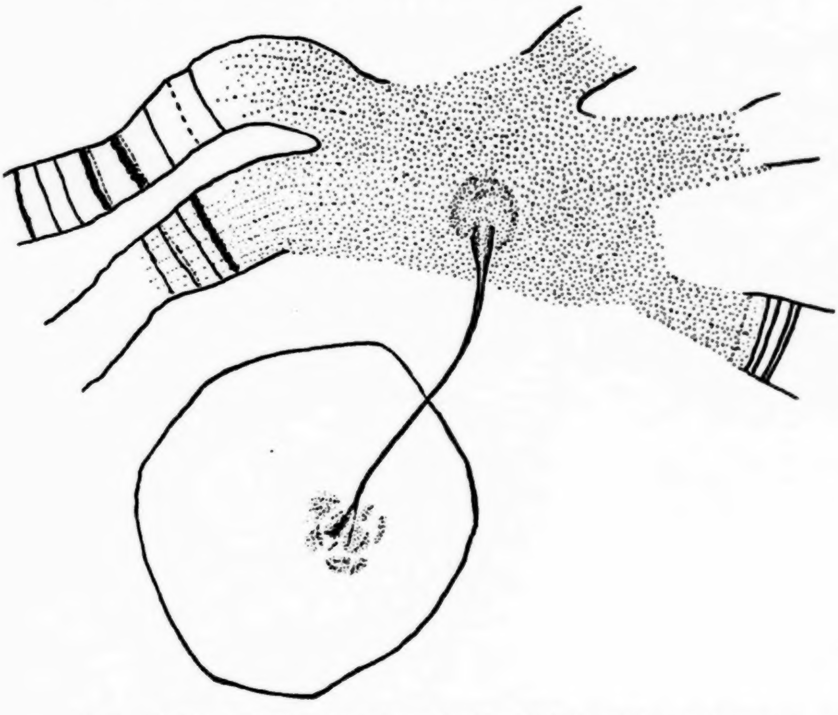


FIG. 7.—Nucleolar connection from salivary gland nuclei of *Drosophila funebris* larvae. ×1700.

Cultures were started, and soon larvae were obtained and the salivary gland nuclei examined. Here at least one of the chromosomes communicates directly with the nucleolus in a similar manner as in the case of *Drosophila busckii* (fig. 8). In *Zaprionus vittiger* II this chromosome can be readily identified by the presence of a large swelling not far from its communication with the nucleolus. The full chromosomal constellation is being worked out by Miss D. Stewart, B.Sc.(Hon.) of the University of

the Witwatersrand. The data so far available seem to show the presence of a chromocentre, but how the other chromosomes communicate with the nucleolus is difficult to ascertain. The staining and spreading of the constellations in this genus are difficult, because the cytoplasm stains relatively deeply and the chromosomes have many loops.

Another very clear indication of intimate communication of the chromosomes or the chromocentre with the nucleolus is obtained from Psychodid larvae. Here the chromocentre and nucleolus communicate so directly that it is difficult to distinguish between heterochromatin and nucleolus, the latter being relatively smaller than in Drosophilids. The only indication of chromocentral material is the presence of many lines in the stream of material connecting the chromosomes to the nucleolus (Pl. V). An interesting phenomenon is the general failing of synapsis in the giant chromosomes of these larvae even in their full-grown condition. These larvae show the broadest communication between chromocentre and nucleolus so far encountered in this Department. Communication here is certainly not merely by means of threads. It is a heavy bridge of material (kalymmatin) containing threads (genonemata) connecting the nucleolus with the chromosomes.

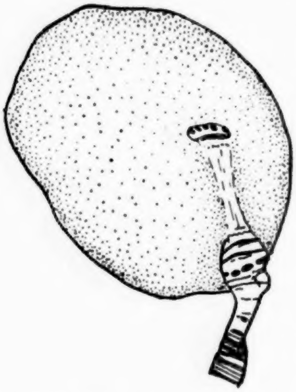


FIG. 8.—Nucleolus showing direct chromosomal connection from salivary gland nuclei of *Zaprionus vittiger* larvae. Drawing by Miss D. Stewart. × 1700.

The above data and considerations seem to justify the conclusion that in the salivary constellations of Diptera so far studied an active communication between nucleolus and chromosomes is present. The whole morphological arrangement of the salivary gland nuclei, especially in the case of *Drosophila funebris*, indicates an economic way of distributing nucleolar material to the chromosomes. Thereby, meaning has been imparted even to the synaptic condition of the chromosomes. From the nucleolus, as a reservoir formed during telophase, the contents again pass as a matrix of each conjugated chromosome pair *via* the chromocentre as a common distributing centre. During telophase, then, the nucleolus is "secreted," only to be used again during prophase. According to this theory the nucleolus becomes a very important body demanding closer study. Ultra-violet photography, spectrographic analysis, and micro-biochemical studies may prove useful lines of attack.

We are greatly indebted to Professor A. H. Sturtevant of the California Institute of Technology, for identification of South African Drosophilids; and to Mr. H. B. S. Cooke of the Department of Geology of the University of the Witwatersrand, for photographs taken.

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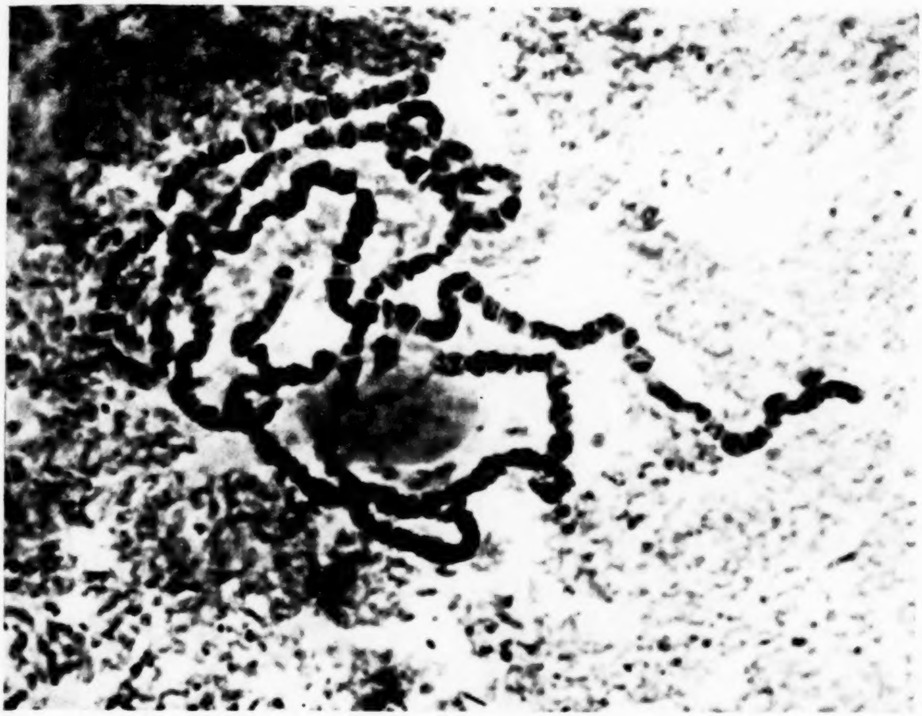
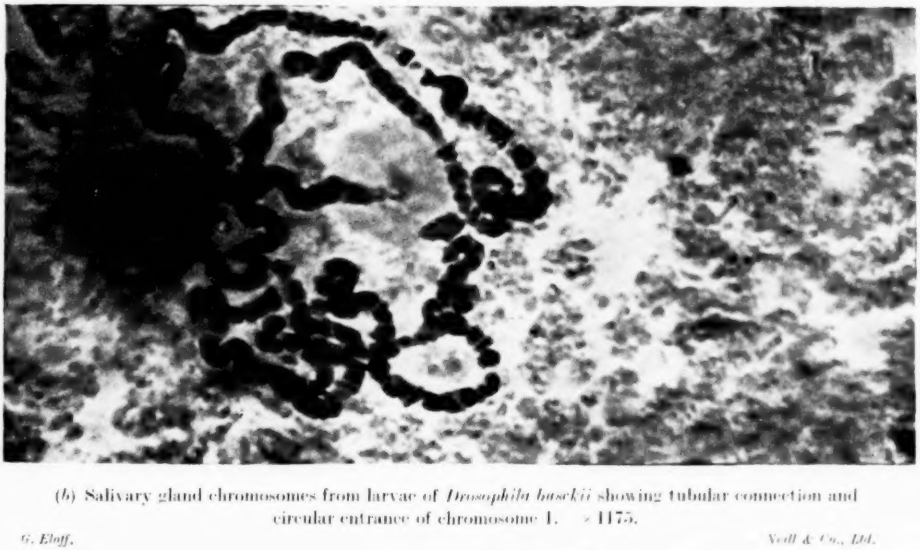


(a) Salivary gland chromosomes from larvae of *Drosophila buskii*. Photo H. B. S. Cooke. See also fig. 3. × 1500.



(b) Salivary gland chromosomes from larvae of *Drosophila buskii* showing tubular connection and circular entrance of chromosome I. × 1175.

G. Eloff. *Neill & Co., Ltd.*

Salivary gland chromosomes from Psychodid larvae showing heterochromatic bridge connecting chromosomes with nucleolus. Note genonemata in bridge and general failure of synapsis. × 1175.

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INTRODUCTION À L'ÉTUDE DE L'HOMME DE LIKASI.

Par F. CABU, Dr.Sc., Anth.

(With one Map.)

(Read April 16, 1941.)

Likasi, se situé à 140 km., par la route, au Nord-Ouest d'Elisabethville, faisant face au centre administratif et commercial de Jadotville, chef lieu du District du Lualaba. Likasi fait partie du groupe Panda-Likasi-Chituru, fief important de l'Union Minière du Haut Katanga qui en fit un centre industriel très important pour le traitement du minerai de cuivre, au cœur de cette "cordillère du cuivre" région plissée de terrains sedimentaires appartenant au système du Kundelungu.

Les plissements de la Zône Cuprifère forment un faiseau oriente de Sud-Est vers Nord-Ouest, dont les plis, d'abord parallèles, s'étalent en éventail dans la region du Nord-Nord-Ouest-Toute la Zône Cuprifère a été affectée par der accidents géologiques: cassures et failles, postérieures aux plissements proprement dits.

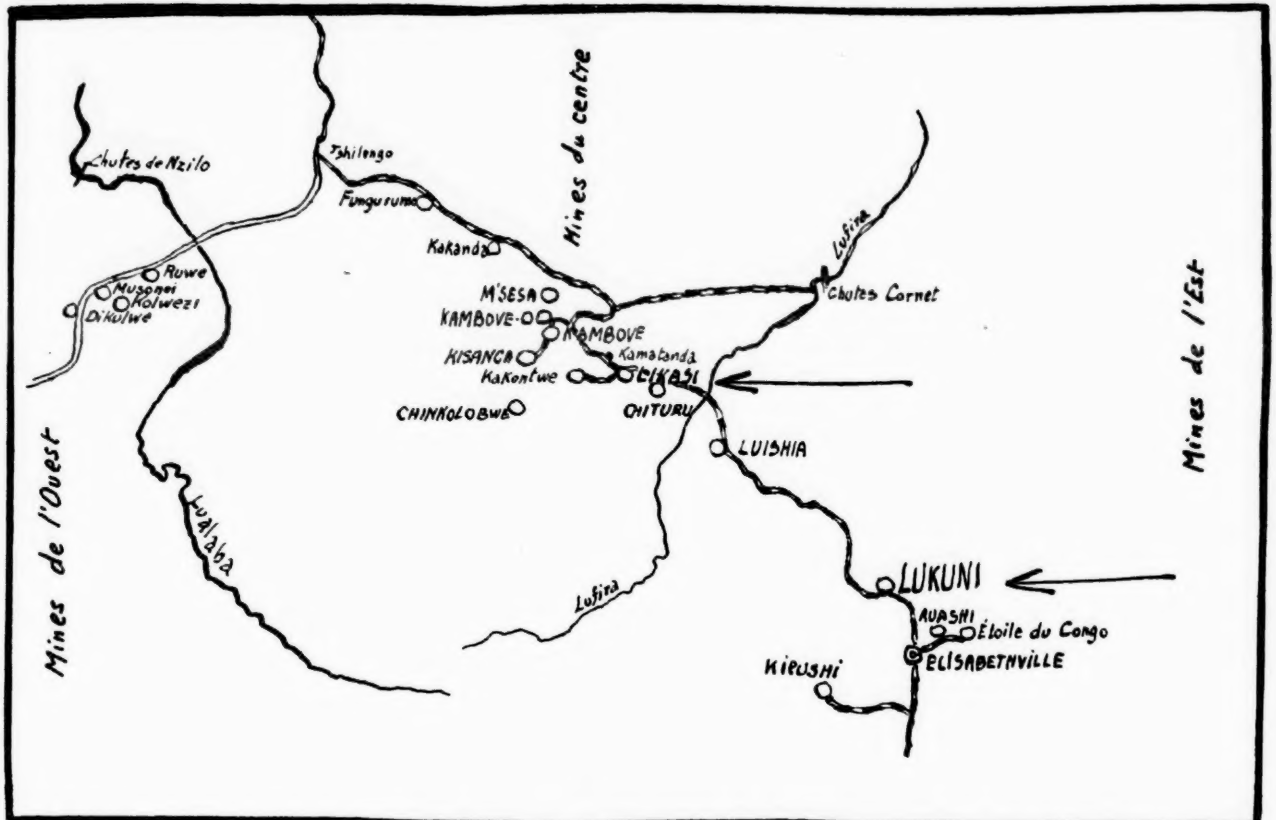
C'est dans ces zônes de cassures que se concentre principalement le cuivre généralement sous forme de carbonates plus ou moins hydratés, de malachite et autres cristallisations aux teintes les plus chatoyantes les unes que les autres.

Ce sont ces richesses minérales qu'exploite actuellement l'Union Minière du Haut Katanga plus connue sous l'abréviation de U.M., mais l'exploitation proprement dite remonte à des temps immémoriaux.

Likasi-Panda, depuis la mort de Mushiri (M'siri) le despote abattu le 19 décembre 1891 par le lieutenant Bodson, dépend du fief de Pande.

Pande est un chef d'un groupe Lunda, les Basanga fixé en territoire de Kambove lors de l'arrivée du fameux potentat despote Katangais: Mushidi ou M'Siri.

M'Siri venait de l'Unyayembe région comprenant le Nord-Est du Tanganika, s'étendant jusqu'au Sud du Lac Victoria et le voisinage de Tabora. Les Wanyamwezi avaient à leur tête un roi réputé: Mirambo surnommé par Stanley: le Bonaparte noir. Les Nyamwezi ont l'esprit aventureux et commerçant. Ce sont des voyageurs ne craignant pas de parcourir en de longues randonnées les régions intérieures de l'Afrique centrale.



Mines de l'Ouest
Mines du centre
Mines de l'Est
Chutes de Nzilo
Tshilongo
Fungurume
Kakanda
Ruwe
Musonoi
Kolwezi
Dikulwe
Lualaba
M'SESA
KAMBOVE
KAMBOVE
KISANGA
Kakontwe
Kamatanda
LIKASI
CHINKOLOBWE
CHITURU
LUISHIA
Lufira
Lufira
Chutes Cornet
LUKUNI
AUASHI
Étoile du Congo
ELISABETHVILLE
KIRUSHI

Mushidi, lors de sa conquête du Katanga se fit accompagner par des gens de Mirambo: les Bayeke. Ces étrangers Bayeke créerent du Luapula au Lualaba un empire nouveau et vers 1850, la conquête du pays par les Bayeke rendit un nouvel essor a l'exploitation minière, mois, dit S. Excellence Mgr de Hemptinne (Rev. Congo, 1926: Les Mangeurs de Cuivre) l'exploitation du cuivre katangais par les Bayeke ne parait pas avoir en l'importance de l'ancien marché Arabe.

A l'arrivée des Bayeke, l'exploitation des mines de l'Ouest fermées depuis longtemps-ne fut pas reprise et les Bayeke ne reprirent l'extraction du cuivre que dans la Zône Centrale comprise entre la Lufira et le Lualaba. Les mines de l'Est abandonnées elles aussi depuis longtemps n'eurent pas d'intérêt pour les nouveaux maîtres des champs miniers.

L'exploitation minière de cette zône s'était pourtant avérée très active a en juger par l'importance des excavations, de nombreux cratères mesurant de 30 à 50 mètres de diamètre sur 7 à 8 mètres de profondeur. L'examen de ces travaux, écrit Mgr de Hemptinne témoigne d'un abandon qui remonte à de longues années. L'érosion est considérable, à l'entrée même des galeries, des arbres ont poussé dans les déblais.

Bien avant l'arrivée de Mushidi et des Bayeke, écrit le Professeur Maurice Robert (Le Katanga physique, Edit. Lamertin, Bruxelles) on faisait du cuivre au Katanga.

Les populations indigènes du Katanga peuvent se rattacher actuellement à trois grandes tribus.·

Les Bayeke, étrangers d'implantation récente venus du Nord-Est;

Les Balubas, venus du Sud-Ouest à une époque très ancienne et établis dans le Nord-Ouest du Katanga;

Les Balunda on Lunda occupant eux aussi des territoires étendus du Katanga et occupant précédemment le pays.

Toutes ces peuplades ont formé de grands empires.

Les Lunda se sont largement étendus dans toute la zône Sud du Kasai et de ses affluents. Le chef des Lunda porte un nom bien connu de ceux qui se sont occupés des questions africaines. Lors de l'apogée de leur puissance au XVIII^{e} siècle, des groupes importants de Lunda se sont dirigés vers l'Est; s'installant sur le Lualaba, puis franchissant ce fleuve poussant plus à l'Est encore, ils franchirent le Luapula allant créer l'empire de Kazembe au Sud du Lac Moero. C'est la capitale de cet empire qu' atteignit de Lacerda en 1798.

Si l'homme de Likasi que le Professeur Drennan m'a fait le plaisir et l'honneur de bien vouloir étudier dans ses laboratoires de l'Université de Cape Town appartenait au groupe Bantou ainsi qu'on l'insinuait malgré mes études préliminaires, il devrait présenter soit des caractères luba, lunda, basanga, voire même bayeke. L'étude du Professeur Drennan

conclut au contraire à sa similitude, sauf en ce qui concerne la capacité cranienne, avec le fossile paléolithique supérieur d'Asselaer, au nord de Tombouctou, en plein Sahara.

Les données que nous possédont sur l'Homme de Likasi sont malheureusement bien fragmentaires. C'est un homme découvert lors de travaux miniers et heureusement sauvé pour la science à cause du caractère spectaculaire de sa minéralisation en vert légèrement bleuté. Ne sont-ce pas des considerations pareilles qui ont sauvé de la destruction le crâne de Broken-Hill, minéralisé au plomb et découvert à l'occasion de travaux miniers?

Le crâne de Likasi fut mis à jour en Janvier 1935 par le chef mineur David accompagné de M. Wery, tous deux de l'Union Minière. C'est en faisant des puits de prospection dans le gisement cuprifère sis près du magasin central que ces travaux de prospection ont recoupé a 8 ou 9 mètres de profondeur une ancienne galerie de l'exploitation indigène ancienne, galerie comblée par des éboulis.

C'est au cours des travaux de déblais, dans cette galerie qu'un squelette fut découvert.

Etait-il intact au moment de sa découverte, c'est ce que nous n'avons pu savoir. Toujours est-il qu'en janvier 1937, visitant le musée géologique de l'Union Minière à Panda, notre attention fut immédiatement attirée par les dimensions anomales de ce crâne par rapport à la longueur de ses os longs, par la dysharmonie de la face par rapport à la boite cranienne, par l'absence d'épine nasale, par son prognathisme sous nasal accentué et par la portion postérieure du crâne plus ou moins étirée en chignon.

Ayant signalé l'intérêt que présenterait pour la science l'étude de ce spécimen humain conservé au cuivre, Monsieur Cousin, Administrateur délégué de l'Union Minière consentit à le mettre à ma disposition pour étude.

Cette étude s'étant révelée intéressante, nous sommes retournés sur l'emplacement, hélas très bouleversé, de la découverte. Aucune étude stratigraphique n'était plus possible. Qu'il nous suffise de dire que la region de Jadotsville est particulièrement riche en industries du paléolithique superieur. Les Kwès sont nombreux dans la région, l'industrie sur quartz également, industrie que nous croyons pouvoir rattacher, dans l'ensemble à l'industrie de Smithfield, de nombreux fours de fonderies indigènes temoignent également de l'intense exploitation du minerai de cuivre.

L'archéologie, l'absence de stratigraphie ne peuvent donc nous être d'aucun secours pour dater ce fossile humain.

REMERCIEMENTS.

Je remercie l'Union Minière et plus particulièrement Monsieur l'Administrateur delégué, Monsieur Cousin, Monsieur Marthoz, Directeur-général, M. Schuiling, Directeur du Musée Géologique, qui m'ont autorisé à emporter cette pièce unique dans les archives de la paléontologie humaine du Congo Belge, mais toute ma gratitude va au Professeur Drennan qui malgré ses importantes fonctions à l'Institut d'anatomie de l'Université de Cape Town, malgré les travaux de correction d'une très importante étude d'anatomie en cours d'impression, malgré nombre d'études en voie d'élaboration, fit, tous travaux cessants, l'étude si détaillée de l'Homme de Likasi, étude qui, corroborant mes conclusions provisoires, est d'un tel interêt au point de vue de la paléontologie humaine.

CAPE TOWN,
16 *avril* 1941.

REPORT ON THE LIKASI SKELETON.

(A Paper from the University of Cape Town.)

By M. R. Drennan,
Anatomy Department, University of Cape Town.

(With one Text-figure and one Table.)

(Read April 16, 1941.)

In all the great osteological collections in the various museums of the world there is a notable absence of any representative group of human remains from the Belgian Congo. As a result of this paucity of material very few studies have been made of skeletons from this part of Africa. The absence of this background adds considerably to the difficulty of assessing the exact status of individual skulls and bones from this area, but it does not detract from their interest or importance. It is, in fact, desirable that as much new data from this territory as it is possible to get should be put on record. The skeleton from Likasi which I am about to describe has the added value that it was discovered under special circumstances and the bones are in a condition that amounts to a degree of fossilization. For the privilege of examining and reporting on this valuable specimen I am greatly indebted to the distinguished anthropologist Dr. Francis Cabu, at the moment in charge of a commission to the Belgian Congo.

The remains consist of a skull without the mandible; a right clavicle, a right scapula, and a right and left humerus; right and left os coxae (hip-bones), a right and left femur, and a very slender fragmentary left fibula; one thoracic and three lumbar vertebrae and a number of complete and fragmentary ribs.

All the bones are impregnated with a green colouring-matter which shows up in patches on their surfaces. In the case of the skull this has a somewhat glossy appearance, as if the skull had been enamelled and the green paint worn off in places. This greenish pigment looks like verdigris or some other green copper salt, most probably cuprous carbonate, because of its insolubility in water.

Weights of the Bones.

In spite of this impregnation with metallic salts the bones are all lighter than usual. This is due to the dryness and porosity of the bony tissue, and, in the case of the skull, to an unusual thinness of the vault. In the temporal and occipital regions this is only 2 or 3 mm. thick, and in the vertex it measures 4 mm. in thickness. The average thickness of the skull in these regions was found to be 4, 6, and 5 mm. respectively in a series of Tropical Bantu Natives studied by Maynard and Turner (1914). The weights of a selection of the bones are as follows:—

Skull	496 gr.
Right humerus	154 ,,
Left humerus	136 ,,
Right femur	434 ,,
Left femur	381 ,,

Sex and Age.

The os coxae has all the characteristics of a male hip-bone, so that there is not much doubt about the sex being male. The skeleton is that of a young individual, but all the epiphyseal lines of the long bones have completely disappeared. The wisdom teeth have erupted but have not yet reached the occlusal plane, so that from these two criteria one would judge this individual to have been between twenty and twenty-five years of age. On the other hand, the fact that the basi-sphenoid suture of the skull is closed indicates that he had completed his twenty-fifth year. The indications, therefore, are that he was approximately twenty-five years of age when he died.

The Cranium.

When viewed from above the cranium presents an oval shape, and it is clearly phaenozygous. Its maximum length is 181 mm. and it measures 131 mm. in breadth, giving a cephalic index of 72·4 which puts it into the dolichocephalic class of skulls. It is thus in shape and in these dimensions and proportions a typical Bantu skull.

Its basi-bregmatic height of 128 mm. is considerably lower than the average height of Bantu skulls, but it comes within the range of variation of such skulls. The height-length index is 70·7, which just brings it within the orthocephalic group of skulls. The height-breadth index is 97·7, which classifies it as metriocephalic. In these latter proportional respects this skull is not so typically Bantu, but I shall discuss this at a later stage in this report.

The cranial capacity of this skull, as measured by the shot method, is 1250 c.c., indicating a considerable degree of microcephaly. In this respect

it falls far short of the average for Bantu skulls, which ranges from 1350 to 1400 in different groups, but these small capacity figures occur sporadically in data from Bantu material (see Table I).

TABLE I.

	Cephalic Index.	Height-breadth Index.	Facial Index.	Nasal Index.	Orbital Index.	Cranial Capacity.
Likasi (Drennan) .	72·4	97·7	50·0	56·8	88·6	1250
Corisco (Shrubsall) .	75·9	101·5	46·9	66·7	88·1	1225
Congo (Shrubsall) .	72·9	100·7	52·5	48·1	97·5	1400
Loanda (1) (Shrubsall)	68·7	105·9	57·6	50·0	86·8	1670
Loanda (2) (Shrubsall)	68·1	96·5	51·8	53·8	83·3	1565
Angola (Shrubsall) .	70·9	107·5	54·5	54·0	84·6	1510
W. African Negroes (Hrdlicka).	74·8	101·3	51·4	60·5	84·9	1360
Bakwa Kalondji (Drennan).	74·3	104·4	?	53·8	93·5	1510
L'homme d'Asselar (Boule and Vallois).	70·9	99·2	50·3	54·9	80·9	1507

When viewed from the side (see fig. 1) this skull presents the typical contour of a Bantu skull, and the only special feature on this aspect is the unusually salient supramastoid crest, which curves upwards from the mastoid region behind the temporal squame. The supra-auricular height is 109 mm., which again is a low figure. From this aspect one can see the moderate degree of prognathism presented by this skull and reflected in a gnathic index of 102·5.

THE FACE.

The face measures 130 mm. in bizygomatic width, and 65 mm. in nasion-prosthion length. This gives an upper facial index of 50, that is to say on the borderline between leptoprosopy and chamaeprosopy, indicating a face of medium length and width. The basion-prosthion length is 103·5 mm., and the basion-nasion length 101·0 mm. Nasal breadth measures 27·0 mm. and the nasal height is 47·5 mm., giving a nasal index of 56·8, which denotes quite a usual degree of platyrhiny in Bantu skulls. The orbital height is 35·0 mm., and the orbital width is 39·5, giving an orbital index of 88·6, indicating that they are mesoseme, which is the prevailing shape in the Bantu. In all its facial features and proportions I regard this skull as typically Bantu.

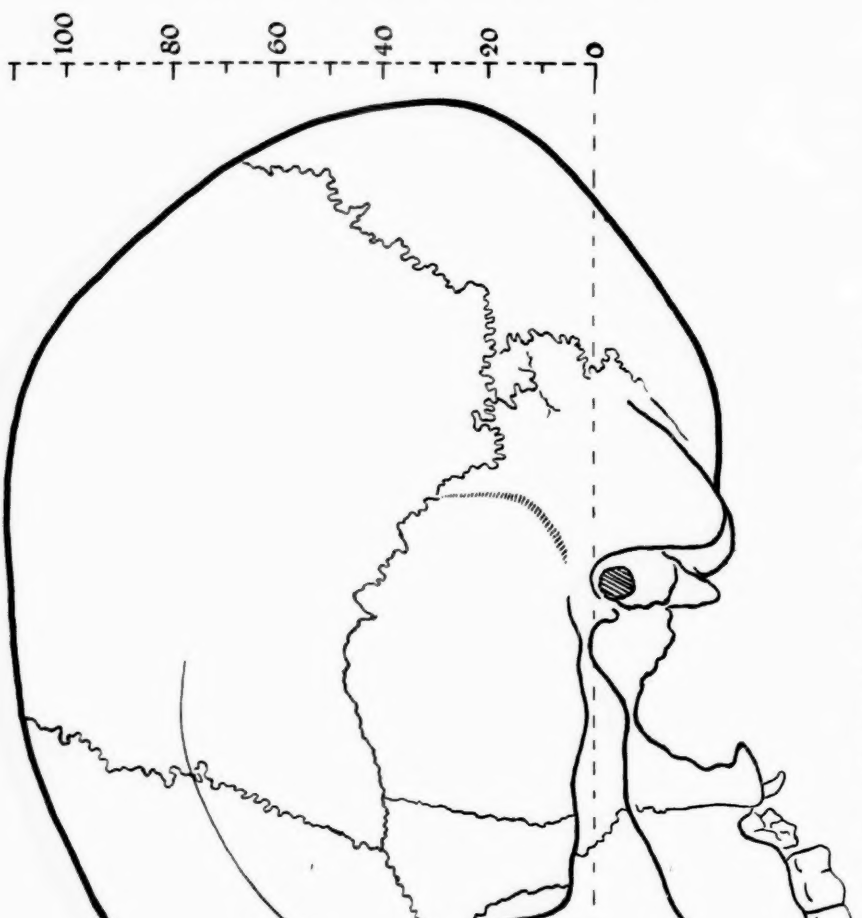


FIG. 1.—Dioptograph projection drawing of the Likasi skull.

Palate and Teeth.

The maximum alveolar breadth is 67·0 mm., and the maximum alveolar length measures 56·5 mm., giving a palato-alveolar index of 118·6, which is met with frequently in Bantu skulls. The height to which the palate rises above the chewing surfaces of the second pair of molar teeth is 19·0 mm. In a study of 84 Bantu palates Middleton Shaw (1931) found that the average height was 19·5 mm., with a minimum of 13·5 and a maximum of 22·0 mm., so that the vaulting of the Likasi palate is not unusual.

The two upper premolars and the first two molars are in place on both sides, whilst the two wisdom teeth are in the process of eruption. These latter are both through the alveolus, but the left one may not have been through the gum. All these teeth are in perfect condition with only a slight degree of attrition and no sign of caries or any other disease. The sockets of the incisors and canines are deep, and look as if healthy teeth had fallen out of them. There is nothing of a pathological nature, such as one would expect had there been any dental mutilation in life.

The teeth which are available for study are all big and well formed with the characteristic tuberculation of upper negro teeth. The measurements of each of them approximate to the maximum size of the Bantu range rather than to the mean. In this respect they are identical to the corresponding teeth in the fossil man from d'Asselar, with the exception of the third molars, which are slightly smaller than in this latter specimen. To this I shall return in my discussion of the affinities of this individual. In the meantime it is sufficient to note that with a total premolar-molar mesio-distal length of 45·8 mm. this skull is megadontic.

The Limb Bones.

The clavicle is fairly robust and measures 152·5 mm. in length. The scapula is likewise well formed, but slightly damaged at its lower angle, thus vitiating its measurement. The right humerus measures 34·0 mm. in maximum length, the left is slightly shorter with a length of 33·8 mm. The average of the index of robusticity for both bones is 18·8, which is quite comparable to the index of 18·2, which Martin (1928) gives for male Massai. These humeri both show the epitrochlear salience of the lower end of this bone, to which Boule and Vallois (1932) draw attention in their monograph on d'Asselar man. It is unfortunate that neither of the bones of the forearm is represented in this skeleton. The cleido-humeral index is, however, 44·8, which is quite a usual proportion in the Negro.

The study of the pelvic girdle is handicapped by the absence of the sacrum. It is possible, however, to give the maximum height of this from that of the right os coxae, which is 214 mm. The maximum breadth of

this bone is 156 mm., so that the index of this bone is 72·9. From this it may be concluded that the pelvis was a relatively long and, I think, also a relatively narrow one.

The maximum length of the right femur is 50·7 mm., that of the left 50·2 mm.; the physiological lengths of these two bones is 50·3 and 49·7 mm. respectively. The pilastering index of the right femur is 102·5, that of the left 104·5, which indicates a low degree of keeling. The average of the upper platymeric indices of the two bones is 79, indicating only a moderate amount of flattening in this region of the femur. The index of robusticity of the femur is 10·8, which is lower than the general run of this index and slightly lower than the figure of 11·8 which Martin gives for the Negro.

Stature.

Only two bones, namely, the humerus and the femur, are available for a calculation of the stature by the usual formulae, and there is a considerable disparity in the result arrived at by using first the humerus and then the femur. Thus by taking the maximum length of the humerus and using Manouvrier's table a stature of 1697 mm. is arrived at. A closely corresponding figure of 1690 mm. is obtained by applying Pearson's regression formula (1899) to the same bone. On the other hand, by applying these two methods to the femur, statures of 1776 and 1759 respectively are obtained.

In trying to account for the disparity in the results derived from the two bones it must be remembered that both Manouvrier's and Pearson's devices were based on data from European material, and that they are not necessarily applicable to the Negro, at least to individual bones and without adjustment.

Martin gives figures which show that the lower limb of the Negro is appreciably longer in relationship to the stature than the corresponding limb of the European, and we know that the femur length is closely correlated with that of the lower limb. It follows that calculations based on the relationship between femur length and stature in Europeans will exaggerate the stature of Negroes.

There is only a slight difference between the ratio of the upper limb to stature in the European and the Negro, but the humerus of the Negro takes a relatively smaller share in the length of the arm than it does in the European, as is brought out by the great difference between the radio-humeral index in the Negro and the European. The relative shortness of the humerus is also brought out by the fact that the humero-femoral index is lower in the Negro than it is in the European. In this particular skeleton the humero-femoral index is 68, showing that we are dealing with a relatively short humerus. Allowance for this would seem therefore to

be necessary, and a considerably taller stature than that arrived at on a European basis seems to be indicated, when dealing with a Negro humerus by itself.

Pearson states that there is justification for taking the mean of divergent reconstructions of stature in certain circumstances, and the mean of the results from his two formulae gives a stature of 1724 mm. Pearson fortunately gives a formula in which the length of the humerus and that of the femur are combined, and when this is applied to the present material a stature of 1731 mm. is derived. I have checked these two latter findings by making proportional allowances for the difference in bone lengths in the two races, namely, by subtracting a percentage from the femur length of the Likasi femur and by adding an appropriate percentage to that of the humerus, and I conclude that a stature of between 1725 and 1730 mm. is a close approximation.

This is slightly above the average stature of S.A. Bantu, which is given by Fritsch as 1718 mm., and it is considerably higher than the average figures given by Deniker (1926) for inhabitants of Angola, such as the Mouchi-Kongo 1660 mm., the Ba-Nchombe 1670 mm., and other Bantu averages. I consider that he would have been looked upon as a tall individual in most Bantu tribes. His stature may indicate some affinity with other still taller negro types.

Discussion.

There is no doubt about the essentially negroid features presented by this skeleton, and I have indicated the directions in which it seems to me to be typically Bantu. In the preceding Table I the chief indices of this cranium are set out for comparison with corresponding indices given by Shrubsall (1898) in his study of Western A-bantu for skulls from this region. I have also included in this table the average indices obtained by Hrdlicka (1928) from seven West African Negro crania from the Gold Coast, the Cameroons, and the French Congo. Included in this table is data from a Belgian Congo skull labelled Grotte de la Bushimaye, Bakwa Kalondji, kindly submitted to me by Dr. Cabu. For reasons which will be given later in this discussion I also add corresponding indices from l'homme fossile d'Asselar (Sahara).

From this table it can be seen that all the indices of the Likasi skull are approximated by one or other of the individual skulls from the Congo region, and that it thus falls within the limits of this narrow range of variation. I think I am justified, therefore, in concluding that this individual would not have been considered a foreign element in the local population of to-day.

It remains for me to give some consideration to one or two of his features

which are furthest removed from the Bantu type. There is now a fairly general agreement amongst anthropologists that the various characters of the skeleton have a genetic background, and thus may be used to establish racial affinities. These need not necessarily be interpreted as pointing to recent admixture; they may merely suggest a possible line of evolutionary descent and common ancestors or contacts long ago.

The first of these characters which I wish to discuss is the low absolute and relative measurements of this cranium. There is no doubt that it is to data from Bushman material that one must go to get the closest approximations to the figures presented by this Likasi skull. The wide spread of the Bushman cultures has now been traced, and it is generally admitted that there is a Bushman element in many of our Bantu tribes. Shrubsall (1896) has actually described a skull from a member of the Mondombe tribe, who inhabit the country between Benguela and Mossamedes, as being undoubtedly a member of the Bush-Hottentot race, and in this connection Shrubsall speaks authoritatively. From a study of all its characters he concludes that "any description of a Bushman skull would suit equally well for this, which is of interest mainly as showing the presence in modern times of members of this race, on the west coast, as far north as the twelfth parallel of south latitude."

What I have said above regarding cranial height applies with equal force to the very low cranial capacity of the Likasi skull, which approximates to the Bushman rather than to the Bantu mean. In other respects the Likasi skull does not suggest any close Bushman affinity, and his large teeth and big stature seem to me to negative anything but a very distant relationship.

A discussion of human remains from the Belgian Congo, especially of a specimen that presents a considerable degree of fossilization and is thus of some antiquity, would not be complete in any case without some reference to the now well-known fossil man from d'Asselar in the Sahara. But when, as it would now appear, Likasi man and Sahara man have been made, if not from the same mould, at least according to the same canons of proportion, it becomes incumbent upon me to direct the attention of anthropologists to the very close similarity which exists between these two fossil types. Fortunately d'Asselar man has been the object of a brilliant monograph by Boule and Vallois, so that I need only refer the reader to the comparisons and discussions of these two distinguished anthropologists. Their conclusions for d'Asselar man apply word for word to Likasi man with this small difference. Largely on account of the size of his skull and great brain capacity Boule and Vallois stressed the Hottentot affinity of Sahara man. I have shown that in the case of Likasi man owing to the smallness of his skull and low capacity it is with

the Bushman that there is some affinity. We know that the Bushman and Hottentot are racially closely allied, the difference being largely a question of size of skull but not of proportion. The difference between the skull of Likasi man and that of Sahara man is of the same order. For the rest, and as regards the teeth and the remainder of the skeleton, including stature, they are more or less identical.

The question now is which of the two apparently incompatible conclusions to which I have arrived is the correct one. Is Likasi man a relatively modern member of the population of the Belgian Congo, such as I have indicated he could be, albeit showing a persistence of archaic features, or is he an ancient type of negro linking backward, as is claimed for d'Asselar man, to primitive African stocks? The structural differences between the former and the latter type of man are not outstanding, and even in the case of d'Asselar man the anatomical facts are somewhat equivocal in these directions. It would seem, therefore, that anatomy cannot give a verdict on this issue, so that it is to the archaeological evidence that one must appeal. I write this report without the benefit or the bias of this information; the bones themselves can speak for relative modernity or for a respectable degree of antiquity.

The Council desires to acknowledge the receipt of a grant from the University of Cape Town towards the cost of publication of this paper.

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METAMORPHOSED SEDIMENTS FROM THE GOODHOUSE-PELLA AREA, NAMAQUALAND, SOUTH AFRICA.

(*A Paper from the University of Cape Town.*)

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(Communicated by F. Walker.)

(With Plate VI and five Text-figures.)

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CONTENTS.

I. Previous Work.

The Basement granites in the area bounded by the Orange River in the north, by a parallel line 10 to 15 miles south of the river in the south, by Goodhouse in the west, and Pella in the east, carry a profusion of sedimentary xenoliths, which probably represent metamorphosed pendants of the Kheis Series.

Two types of highly uncommon mineralogical and chemical composition have been described elsewhere, viz. a sillimanite-corundum rock,[6] and an anorthite-epidote-garnet hornfels,[8] which are tentatively referred to the depth metamorphism of bauxitic and marly materials respectively. The affinities of the granites whose emplacement generally supplied the energy for the transformations formed the subject of a paper by the author on The Petrology of the Goodhouse-Pella Area in Namaqualand, South Africa.[7] This communication is accompanied by a geological map (scale, 1 : 150,000) which depicts the distribution of the xenoliths figured in the succeeding pages.

II. The Sillimanite-bearing Xenoliths.

A. The Sillimanite Augen-Gneisses.

(a) *Petrography.*—The high-grade metamorphism of aluminous-argillaceous sediments by the Younger Granite has led to the formation of a variety of xenolithic sillimanite-gneisses which are listed below:

(1) Sillimanite-quartz-feldspar augen-gneiss was observed on Witbank and Pella, where it is found at the base of the quartzites in association with (2). The eyes are produced by lenticular aggregations of quartz and perthite, and of quartz, sillimanite, and fibrolite respectively.

(2) Sillimanite-quartz-muscovite augen-gneiss occurs as small xenoliths in the granite throughout the entire area. The stout lenses, 9 mm. × 22 mm., of quartz and fibrolite are set in a base of quartz, muscovite, and sericite, and the plates of muscovite are moulded on the surface of the nodules.

(3) Sillimanite-quartz-biotite augen-gneiss was noted in the injected biotite gneisses at Pella and Naroep. The quartz-fibrolite lenses are more flattened and less spheroidal, and they are cemented by granoblastic quartz and biotite, with some muscovite, sericite, and microcline in addition.

(4) Sillimanite-quartz gneiss forms a pear-shaped xenolith 40 yards long and 15 feet thick on Garganab. It consists uniformly of elongated quartzes, with muscovite and fibrolite in parallel arrangement.

(b) *Petrology.*—Community of origin is suggested by an "index" mineral, probably a ferriferous rutile, which is common to the rocks of this series. The following data were utilised in its identification:—

$$\text{Uniaxial positive,} \qquad n > 2{\cdot}10, \qquad G > 4{\cdot}10.$$

The colour is reddish brown, the pleochroism faint, and the lustre in reflected light adamantine. After digestion with conc. HCl, to remove oxides of iron, the grains were moderately magnetic and gave reactions for Fe^{++} and *Ti*.

This genesis is also indicated by the qualitative and quantitative agreements between the modes of the *sillimanite-bearing areas* in different

specimens. From these considerations it seems reasonable to contend that the parental aluminous rocks were of similar compositions, and may have consisted of a particular sedimentary bed at a specific stratigraphic horizon. The differences in mineralogical composition and texture may be attributed to lateral variations, and the original was probably of a conglomeratic nature with quartzo-aluminous pebbles cemented by a matrix of feldspathic or micaceous composition.

TABLE I.

Modes of Sillimanite-bearing Areas.

	(1).	(2).	(3).	(4).	(5).
Quartz	65·1	56·8	64·0	56·7	60·7
Sillimanite . . .	33·4	42·2	34·7	40·0	37·6
Accessories . . .	1·5	1·0	1·3	3·3	1·8
Muscovite . . .	+	+	+	+	+
Rutile	+	+	+	+	+
Iron Ore . . .	+	+	+	+	+
Zircon	+	+	+	+	+
Biotite	−	−	+	−	+

Note.—The numbers at the head of the columns refer to the rocks on the previous page, and (5) is the average of (1), (2), (3), (4).

B. An Occurrence of Sillimanite-Quartz Nodules in the Aplogranite.

(a) *Field Occurrence.*—The exposure is situated in a ravine near the western boundary of the Pella Mission, and 1·5 miles due east of the homestead of Klein Pella. The Kheis sediments consist of a lens of biotite-feldspar gneiss (breadth = 4½ feet) with protruding streamers into the surrounding granite. The latter, over a distance of 19 feet on the southern side of its contact with the xenolith, carries numerous sillimanite-quartz knots, which show in relief with a dead white colour and silken lustre. From the contact outwards the nodules progressively decrease in diameters (from 35 mm. × 20 mm. downwards), the elongation ratios of the spheroids increase, and eventually they disappear entirely.

(b) *Petrography.*—The granite is a reddish, medium-grained, gneissose aplite whose lateral gradations are appended in Table II. The mafic constituent is a brown biotite ($\beta = 1{\cdot}636$, $2V_x = 12°$), which is extensively replaced by a green mica, probably a hydrobiotite with $\beta = 1{\cdot}625$, and X = yellow, Y = Z = olive green.

TABLE II.

Modes of the Contact Aplogranites.

	(1).	(2).	(3).	(4).	(5).
Quartz	45·4	43·1	42·0	40·2	23·3
Microcline . . .	37·8	33·1	42·9	38·0	2·3
Oligoclase . . .	7·5	16·4	11·1	18·5	45·0
Biotite and Accessories .	9·3	7·4	4·0	3·3	29·4
Total feldspar . .	46·5	49·5	54·0	56·7	47·3
Feldspar: quartz . .	1·0	1·2	1·3	1·4	2·0
Av. longer diameters of larger quartzes, mm. .	·4	·4	·8	·9	. .
Av. longer diameters of larger microclines, mm.	·5	·5	·9	1·0	. .

Note.—(1), (2), (3) are contaminated aplogranites collected at intervals of 7 feet over a line perpendicular to the length of the biotite-feldspar gneiss. The modes were determined on the granitic areas between the sillimanite-quartz nodules. (4) is the normal aplogranite 100 feet from the sedimentary xenolith.

The nodules are composed of fasciculated sillimanite, muscovite, and quartz, which is invariably penetrated by needles of fibrolite. The megascopic habit of the nodules is illustrated by the sliced surface in Plate VI, fig. 1. The mode of the biotite-feldspar gneiss is tabulated in column (5); the plagioclase corresponds to $Ab_{80}\,An_{20}$; the biotite has $\beta = 1{\cdot}637$.

(c) *The Genesis of the Nodules.*—From the calculated compositions of the contact rocks in Table III it is evident that the quartz-sillimanite nodules could not have developed in the aplogranite in consequence of the assimilation of the biotite-feldspar gneiss. Reaction between (1) and (2), accompanied by the precipitation of (3), would effect a prominent basification of the aplogranite matrix (4) with respect to the silica percentage, which is, however, identical with that of the uncontaminated rock (1). Similarly, assimilation would produce a higher percentage of Na_2O, and a lower percentage of K_2O, than is the case in column (4). Contamination of the aplogranite by sedimentary matter is nevertheless implied by (*a*) the occurrence of sillimanite in the nodules, (*b*) the development of muscovite in greater quantity than is common in the normal rocks of this group, and (*c*) the progressive decrease in the quantity of biotite and accessories south of the contact.

TABLE III.

Calculated Compositions of the Contact Rocks.

	(1).	(2).	(3).	(4).
SiO_2	77·8	63·9	75·1	77·1
Al_2O_3	11·8	15·8	23·7	10·3
Fe_2O_3	·3	2·2	·3	·7
FeO	·5	4·3	·2	1·4
MgO	·3	2·7	..	·9
CaO	·8	2·2	..	·4
Na_2O	1·8	4·5	..	·8
K_2O	6·6	2·8	·1	7·2
MnO	..	·2	..	..
TiO_2	..	·4	·5	·1
H_2O	..	·9	·1	·3
Totals	99·9	99·9	100·0	99·8

(1) Uncontaminated aplogranite.
(2) Biotite-feldspar gneiss.
(3) Average composition of sillimanite-quartz nodules.
(4) Aplogranite with foreign nodules.

The excellent agreement, shown below, between the average modal compositions of the sillimanite-quartz nodules, and the sillimanite-bearing areas of the augen-gneisses in Table I, suggests the correlation of the nodules with the gneisses, and this view is confirmed by the fact that the

	(*a*).	(*b*).
Quartz	60·7	61·0
Sillimanite	37·6	37·0
Accessories	1·8	2·0

(*a*) Av. of the sillimanite-bearing areas in the augen-gneisses.
(*b*) Av. of quartz-sillimanite nodules in the aplogranite.

ferriferous rutile is common to either set. According to this deduction, the nodules would have attained their present position by the incorporation into the aplogranite of a sedimentary bed, which was lithologically similar to the parent of the sillimanite-augen-gneisses, and probably adjoined the biotite-feldspar gneiss on the south. The latter follows from the unilateral

distribution of the knots, *i.e.* they occur along the southern contact with the gneiss only, and they diminish in quantity as the distance from the contact increases. The oval and spherical shapes of the nodules appear referable to either a conglomeratic structure in the sediment or to a partial digestion and rounding of foreign fragments, which is a phenomenon that finds a large scale counterpart in the enclaves enallogenes associated with many igneous masses.

The aplogranite with its nodules is reminiscent of a paragraph by du Toit on the Geology of Mount Currie, etc.[11] (p. 90). "The (Dwyka) tillite is cut by a sill of dolerite . . . and at the crest of the ridge the intrusion is found to contain in certain parts of its mass numbers of small pebbles, mostly of quartz or quartzite. It is clear that the fragments of tillite were broken off and attacked by the igneous rock, which melted and absorbed the matrix of the tillite, though unable to digest the more refractory inclusions of the latter."

III. The Quartzites.

(a) *Petrography.*—Microscopically the typical quartzites conform to a coarse-grained saccharoidal type in which all traces of distinction between original constituents and secondary cement have completely disappeared. The quartzes of the mosaic attain long diameters of 10–15 mm., and have sutured boundaries which fit into the crenulations of the adjoining elements.

A schistose representative with granoblastic grains ·6 mm. in diameter was observed in a sheared band close to the northern spring on Kambreek, but for the bulk of the quartzites the fabric is isotropic rather than anisotropic.[12] The common accessories are zircon, apatite, biotite, chlorite, muscovite, and iron ore. Titanite, red rutile, hornblende, and epidote are occasionally observed; pyrite occurs locally. High magnifications indicate sercite needles and inclusions of liquid and gas.

(b) *Optical Anomalies in the Quartz.*—Undulatory extinction or strain shadows, which are the mechanical after-effect of orogenic movements, are observed as a dark patch which sweeps across the crystal when the stage is rotated between crossed Nicols. It is ascribed to the influence of unequal pressure on the optical ellipsoid, whereby the ellipsoid of rotation is altered to a triaxial ellipsoid, and in consequence of which the quartz assumes, and sometimes shows, an anomalous biaxial character.[19]

In some of these quartzites the effects of strain appear to be responsible for a structure of sufficient peculiarity to merit description and interpretation. In the interests of clarity the description is confined to one individual which shows the feature particularly well. A large quartz crystal, the sectioned part of which measured 17 mm. × 10 mm., appears in polarised light to consist of ∓ 55 separate layers, each composed of a

variable number of granules with individual lengths from ·1 mm. to 1·0 mm. The interspaces between the larger somewhat rectangular granules are filled by a set of smaller granules, which differ from the larger also in their optical orientation. On rotation this composite crystal behaves as a unit: its outlines are traced by crenulated margins, and a continuous shadow, similar to that observed for normal undulose extinction, sweeps across its "integral parts." The superimposed layers, however, neither extinguish simultaneously over the whole surface of the compound grain nor simultaneously along the length of any one layer (Plate VI, fig. 2). Under the high power in transmitted light the contact between the aggregated crystal and its neighbours is clearly marked by the Becke line, but this effect is never obtainable among the granules themselves. In the conoscope basal grains exhibiting this structure show a rather faint separation of the isogyres.

(c) *Explanation of the Optical Anomalies.*—During the course of its history the coarse-grained quartzite was subjected to stress which caused a translation of the lattice orientation of the quartz individuals probably parallel or sub-parallel to the prism planes.[12] A series of fine parallel faults and strain shadows were produced. When the elastic limits of the quartz were exceeded there followed a partial brecciation of the faulted lamellae, but the intensity of the deformation was such as to retain the continuity of the structure of the original quartz element. Under these conditions the fractured grains approximately preserved the arrangement of their indicatrices, not only mutually parallel to one another, but parallel also to that of the parental grain. During a period of subsequent annealing or recrystallisation the small crystals were enlarged at the expense of the larger ones, ruptures were obliterated, and a greater equality of granularity was established.

Another strain effect sometimes observed in grains cut at a small angle to the horizontal axes consists of a very weak cross-hatched structure, in which one set of striations is dominant and the other subordinate. This effect may possibly be referred to orientations connected with translation or twinning on rhombohedral planes, as was pointed out by Sander.[12] Conversely, it may be an intermediate stage in the production of the structure described above.

(d) *The Stability of Zircon in Metamorphism.*—This point may be briefly considered before alluding to the significance of the mineral in the quartzites. According to Harker,[17] highly refractory zircon remains intact even in the highest grades of metamorphism. Armstrong [2] figures a deformed zircon—from an igneous gneiss—which has acquired a secondary crystal face due to local solution and recrystallisation under stress. Doelter [10] records the synthesis of zircon by different experimenters at 700°–1000° C.

and at a low red heat respectively. Shand[25] mentions the late crystallisation of the mineral in zircon-rich rocks where it has even enclosed albite and nepheline. Brammall[5] suggests the crystallisation of residual zirconia when the main portion of the mafic content of the magma had already separated out.

These observations show that the crystallisation of zircon has been observed at temperatures far below its melting-point ($\mp$ 2000° C.).[10] They cast a reasonable doubt on its refractoriness and indicate the possibility of recrystallisation under metamorphic stress, which would imply that rounded zircons need not be an invariable concomitance of parametamorphic rocks.

(e) *The Rounding of the Zircons.*—Zircon, the most abundant residual mineral in this group, was studied in heavy concentrates which were obtained by centrifuging in bromoform a carefully pounded and elutriated crush which had passed a 120 sieve.

Since the roundness of the zircons has a fundamental bearing on the origin of the quartzites it was endeavoured to determine this property quantitatively. A sedimentary origin is believed to be confirmed if it is established that the average length-breadth ratio of the zircons in the quartzites is substantially less than this value in (1) igneous rocks and (2) sedimentary rocks, in which the rounding is so limited as to permit the recognition of the pyramidal faces. Figures of the latter type determined by Wasserstein[26] varied between 2·5 and 3·0. The application of the elongation ratio is, however, subjected to many objections: it is dependent on the crystal habit, which is a factor variable not only between different eruptive masses, but also within a single mass.[16] Such differences will be reflected in the derived sediment, and a well-rounded longitudinal crystal may consequently have an elongation ratio much greater than that of an unrounded stumpy individual.

These difficulties were in part amended by compiling frequency curves (fig. 1), and considering, instead of the average elongation ratio, that elongation index which has the greatest frequency. The figures, provided discrimination by colour, zoning, inclusions, etc., was already effected, thus become limited to the crystals with the most prevalent habit. In conjunction with the data in Table IV the following inferences seem justified:—

(1) The average elongation ratio and the elongation index of the zircons with the greatest frequency, in the quartzites, are quite comparable with the values of a typically sedimentary rock, but not compatible with the values of the two igneous rocks.

(2) The percentage of rounded zircons in the quartzites is similar to that in the T.M.S.

(3) The greatest observed indices in the quartzites and the sediment are well below those in igneous rocks, which is a natural consequence if it is borne in mind that long slender individuals are the least likely to survive the forces of corrosion.

TABLE IV.

Comparative Data on the Zircons.

	(1).	(2).	(3).	(4).	(5).	(6).
Percentage "Heavy Minerals"	·16	·29	1·04	·37	..	..
Av. elongation ratio of 150 zircons	1·74	1·86	1·79	1·92	3·07	2·31
Percentage zircons with elongation ratio > 3·5 .	0	·6	0	·6	19·3	7·0
Av. size of 20 zircons in mm..	·09 × ·05	·11 × ·06	·09 × ·05	·10 × ·05	·17 × ·06	1·65 × ·70
Greatest observed elongation ratio	3·5	4·0	3·2	3·7	12·8	5·0
Precentage zircons obviously rounded	80	50	55	65	< 5	0
Elongation ratio of zircons with greatest frequency .	1·73	1·75	1·67	1·73	2·25	2·05

(1) Quartzite, Springputs.
(2) Quartzite, north Rozynbosch.
(3) Quartzite, central Rozynbosch.
(4) Quartzite, T.M.S., Mosselbay.
(5) Granite, Cape Peninsula.
(6) Granite, Paarl.

(f) *Origin and Correlation of the Quartzites.*—The Namaqualand quartzites were formerly considered to be non-sedimentary, but in 1928 Merensky suggested that they are highly recrystallised rocks of sedimentary origin. Gevers [14] confirmed Merensky's view from field observations in the area east of Steinkopf, and concluded: "The quartzites in question are therefore probably highly recrystallised representatives of the Kaaien Quartzites, a conspicuous member of the Kheis System * in the area further east." Mathias [20] regards the Namaqualand quartzites as an older quartzitic member of the Kheis System * by virtue of their more intense recrystallisation as compared with the Kaaien Quartzites in the type area, Marydale and Upington. But the latter argument is hardly acceptable, since the extent of recrystallisation depends on a greater number of factors [15] (which may vary from place to place) than relative age, *e.g.* water, heat, load, stress, porosity.

* Professor Gevers and Dr. Mathias both use the term Kheis *System*, whereas in the geological column adopted by the Geological Survey of the Union in 1936 the Kheis *Series* is regarded as a subdivision of the Swaziland *System*, which agrees with the practice introduced by Dr. Rogers,[23] and by Dr. Rogers and Dr. du Toit,[24] but since the intercorrelation of the Swaziland System is very imperfectly known, the discrepancy is of little consequence.

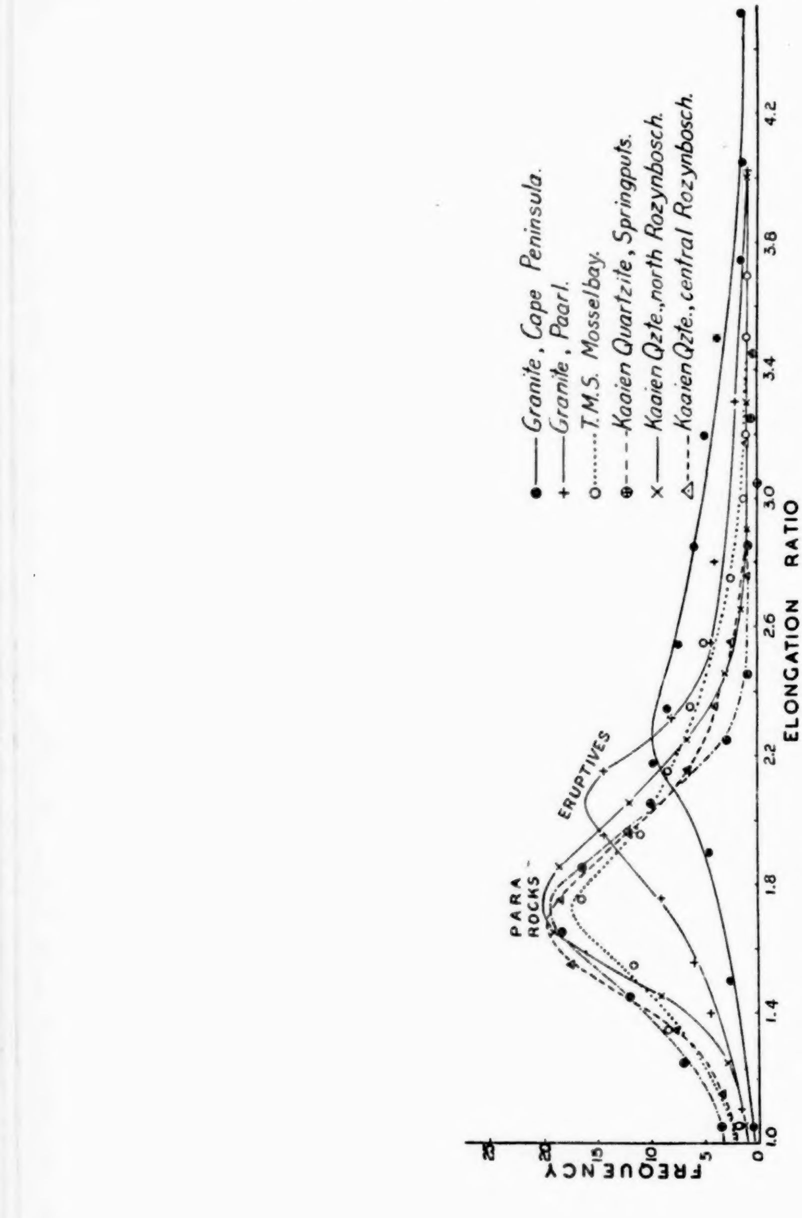

Fig. 1.—Frequency curves for zircon crystals. The peak frequencies for para-derivatives and eruptives are related to appreciably different figures for the corresponding elongation ratios.

The conclusion that "the Namaqualand quartzites generally grade into quartz-muscovite schists while this is not often the case with the Kaaien Quartzites," [20] is furthermore contradicted by the observations of Rogers, who remarks that the Kaaien beds in the type area "consist almost entirely of quartz-schists, quartzites, and mica-schists." [23]

In the Goodhouse-Pella area a sedimentary origin is reflected by the following observations:—

(1) The younger granite-gneiss is intrusive into the quartzites, as demonstrated by relicts of the latter folded into the granite. Plate VI, fig. 3, shows a tilted quartzite band 7 feet in vertical thickness and persistent in length for several hundred yards, overlain by aplogranite.

(2) Continuity of strike is well exemplified by the two converging quartzite ridges which form the eastern part of the Dabenoris mountains.

(3) The quartzite caps of the prominent mountains are underlain seemingly in a "conformable relationship" by a series of sedimentary biotite injection-gneisses. An intercalation of sillimanite-quartz-feldspar augen-gneiss at the base of the quartzites was observed on northern Pella at the locality indicated on the map.[7]

(4) The zircons in the quartzites exhibit a degree of rounding which is similar to that in rocks of known sedimentary origin.

(g) *Temperature of Recrystallisation of the Quartz.*—The quartz contains elliptical, rectangular, and irregular inclusions of liquid and gas. They are more abundant in, but not confined to, sets of trains which show some degree of sub-parallelism. The gas bubbles are either passive or in a state of active Brownian movement, and the proportion of gas is remarkably constant in all the rocks examined. The average diameters of six comparatively large oval cavities are $6{\cdot}0 \times 10^{-3}$ mm. $\times$ $4{\cdot}6 \times 10^{-3}$ mm., and the average radius of the gas bubble is $4{\cdot}0 \times 10^{-4}$ mm. On the supposition that the cavity takes the form of a prolate spheroid, the calculated quantity of included gas is of the order of 1 per cent.

If it is granted "that the cavity was filled with liquid and that the volume of liquid was sufficiently independent of the pressure so that the amount of cooling can be determined from the decrease of volume," [4] then the percentage of gas suggests the tentative conclusion that the quartz has recrystallised at a low temperature,[15] well below the point of refusion, which is a state that seems to obtain in the genesis of some regionally metamorphosed rocks.

(h) *Occurrence of Iron Ore in the Quartzite.*—A small epigenetic lode deposit occurs in the quartzite along the western boundary of Pella farm.

The quartz is replaced by a mixture of hæmatite and magnetite which are in a proportion of 1·0 to 1·4 respectively, and the former appears pseudomorphous after pyrite. In a picked specimen the ratio of gangue to ore equalled 5·3 to 1·0. Muscovite flakes, stained a brilliant red by oxides of iron, form a fringe to the opaque minerals or are included by them, and the heavy concentrate carried an abundance of strongly zoned brownish zircons.

IV. The Injected Biotite Gneisses.

(a) *Petrography.*—The high biotite content of some varieties of the younger granite-gneiss have been ascribed to the assimilation of biotite schists and other originally argillaceous rocks of the Kheis Series.[14] The fringe of biotite gneiss at the foot of the quartzites provide an excellent illustration of the initial phases of this process, especially where the types in question form the clean bed-rock of the tributary ravines.

The layering of the injection gneisses arises from the distribution in well-separated portions of the sedimentary or injected and the igneous or injecting components. The granitic material invaded the semipelitic host presumably parallel to the foliation planes, which led to the development of uniformly striped gneisses with biotite selvages bordering the aplitic veins. The latter in turn may bifurcate at a low angle, bulge into quartz-feldspar augen, or when juxtaposed produce thick compound veins.

(b) *Petrology.*—It is difficult to assess the rôle played by permeation or imbibition, viz. the soaking of country rocks by vapours from the injecting magma with the production of types in which there is no discrete separation of igneous and sedimentary material.[22] For while the two theoretical phases of the process of granitisation, *i.e.* chemical metasomatism induced by permeation, and mechanical mixture or injection are self-evident, it may be impossible in practice to delineate, as a result of their successive operations, the end of the first and the beginning of the second phase.

The mineral compositions of eleven biotite gneisses (from the lower Pella ravine), which may be dominantly of the imbibition type, are set forth in Table V; it was endeavoured to exclude material formed by mechanical admixture on the assumption that the latter is recognisable by banded examples. The selection comprises a uniform set of medium-grained gneisses consisting of quartz, oligoclase, microline, and biotite, with accessory apatite, zircon, titanite, magnetite, allanite, and epidote.

In fig. 2 an attempt was made to generalise the data above by plotting the percentages of quartz and oligoclase and of microcline and biotite as ordinates and abscissae respectively. The linear relationship which seems to apply may be interpreted as a progressive reconstitution of the sediments

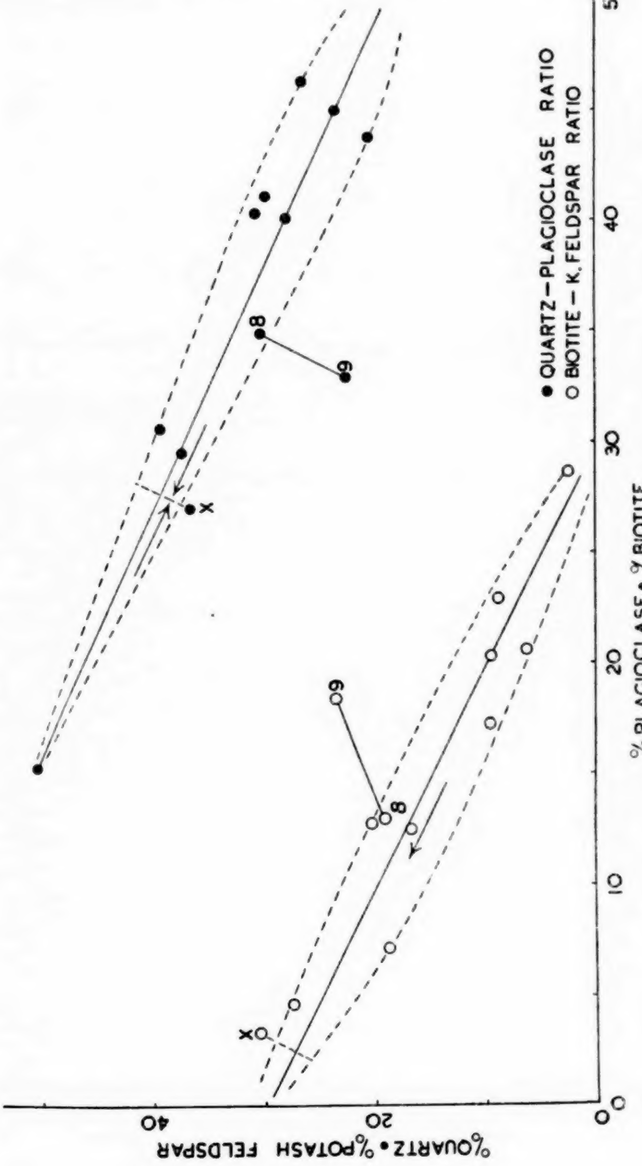

FIG. 2.—Modal relations of the permeation gneisses. The sediments appear to be progressively reconstituted to the composition of the younger Namaqualand granite-gneiss represented by point X.

TABLE V.

Modal Compositions, etc., of the Permeation (?) Gneisses.

	(1).	(2).	(3).	(4).	(5).	(6).	(7).	(8).	(9).	(10).	(11).	(12).
Quartz . .	50·7	20·5	37·3	30·3	23·3	26·4	29·8	30·2	22·4	39·1	28·0	36·6
Oligoclase .	15·3	43·7	29·5	40·3	45·0	46·4	41·0	34·9	32·8	30·6	40·0	27·0
Microcline .	8·9	20·1	27·3	6·1	2·3	18·9	9·8	19·5	23·4	16·8	9·5	30·3
Biotite . .	22·9	12·7	4·6	20·6	28·6	7·1	17·2	12·9	18·4	12·5	20·5	3·3
Accessories .	2·2	3·0	1·3	2·7	·8	1·2	2·2	2·5	3·0	1·0	2·0	2·8
Per cent. An in Plag. . .	30·0	30·0	32·0	37·0	20·0	33·0	32·0	31·0	30·0	23·0	29·0	27·0
Biotite . .	..	..	..	..	..	..	1·640	..	1·648	..	..	..

(12) Average composition of younger granite-gneiss.

to a composition approaching that of the intrusive which is responsible for the granitisation. In this connection the anomalous position occupied by point (9) is very illuminating, since it represents a "xenolithic core" which was relatively less affected by additive processes than the surrounding mantle (8).

V. THE AMPHIBOLITES.

(a) *Petrography.*—Next to the quartzites and the associated biotite gneisses, a series of hornblendic rocks constitute the most prevalent unit of the altered sediments; in size they grade from the large mass, 2·5 miles in length, exposed on Wortel to small bodies of swarm-like habit with but a few feet in individual diameters.

The amphibolites display a well-defined gneissic texture and range from fine- to medium-grained types. The relative proportions of the minerals, their association, and the compositions of the amphibole, pyroxene, and plagioclase, are subject to wide variations, as shown in Tables VI and VII. The amphiboles are pleochroic in shades of X = yellowish green, Y = green, Z = deep green, but the intensities of the tones vary in different cases. The pyroxenes have a greenish tint and exhibit a fair range in composition (fig. 3), as determined by plotting the optical constants in the diagram figured by Deer and Wager.[9]

(b) *Classification.*—The main selection of the amphibolites may be divided into two groups, (*a*) and (*b*), cited in Tables VI and VII respectively. The reasons for this division into different groups are (1) the similarity in the anorthite content of the plagioclase, (2) the resemblances in the optical properties of the amphibole, and (3) the association of the different types in separate fields in the triangular diagram. These relationships are illustrated in Table VIII and fig. 4 respectively.

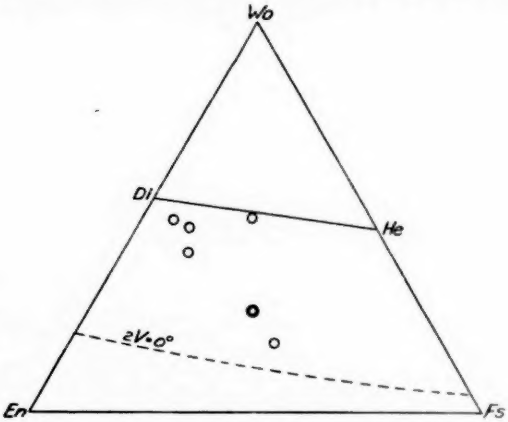

FIG. 3.—Compositions of some metamorphic pyroxenes from the amphibolites.

TABLE VI.

Group (a).

		(1).	(2).	(3).	(4).	(5).	(6).
Plagioclase		32·1	32·7	47·2	45·9	68·9	31·6
Amphibole		65·4	52·4	29·6	26·2	2·0	56·0
Pyroxene		2·5	9·5	16·1	21·0	22·5	..
Rest			5·5	7·1	6·9	6·6	12·4 *
Per cent. An in Plag.		83	90	97	97	87	92
Optical Constants of Pyroxene.	α	1·682	1·680	1·704	1·710	1·722	..
	β	1·688	1·684	1·708	1·712	..	..
	γ	1·706	1·706	1·728	1·734	1·697	..
	ZVz	57°	54°	48°	36°	59°	..
	$Z_\wedge c$	40°	41°	44°	43°	44°	..
Composition of Pyroxene.	Wo	48	41	26	17	50	..
	En	41	45	37	37	26	..
	Fs	11	14	37	46	24	..
Optical Constants of Amphibole.	α	1·642	1·647	1·658	1·654	1·652	1·649
	β	1·658	1·663	1·666	1·659	..	1·658
	γ	1·667	1·672	1·676	1·667	1·672	1·669
	2V	−74°	−66°	+86°	+81°	..	−83°
	$Z_\wedge c$	17°	18°	23°	21°	..	18°

* Comprises saussurite = 6·8 per cent., magnetite = 2·8 per cent., ilmenite = 1·0 per cent., apatite = 1·8 per cent.

TABLE VII.

Group (b).

		(1).	(2).	(3).	(4).	(5).	(6).	(7).	(8).
K. felspar		4·3	·8	13·2	17·6	11·6	..	1·4	4·8
Plagioclase		28·9	61·7	39·3	47·1	32·2	48·6	45·8	32·0
Quartz		15·3	26·2	30·3	12·2	24·9	27·3	5·0	41·5
Biotite		24·2	..	..	4·0	19·0	..	..	} 19·9
Amphibole		26·3	8·7	10·1	15·9	10·1	22·3	44·1	
Pyroxene *		..	..	4·3	..	..	..	..	..
Rest		1·0	2·6	2·8	3·2	2·2	1·8	3·7	1·8
Per cent. An in Plag.		48	37	55	31	37	47	47	41
Optical Constants of Amphibole.	α	1·666	1·660	1·675	1·669	1·669	1·672	1·667	1·665
	γ	1·683	1·675	1·695	1·687	1·688	1·690	1·685	..
	2Vx	57°	59°	60°	50°	50°	55°	56°	..
	$Z_{\wedge}c$	18°	21°	21°	18°	19°	17°	18°	..
Biotite		1·637	..	..	1·635	1·635	..	..	..

* The optical constants of the pyroxene are:
$\alpha = 1{\cdot}705$, $\beta = 1{\cdot}708$, $\gamma = 1{\cdot}729$; $2Vz = 48°$; $Z_{\wedge}c = 43°$.

TABLE VIII.

	Group (a).	Group (b).
Per cent. An in Plagioclase	83–97	31–55
α Index of Amphibole	1·642–1·658	1·665–1·675
γ Index of Amphibole	1·667–1·676	1·675–1·695
Optic character of Amphibole	pos. or neg. 2V = 66° – 86°	neg. 2V = 50° – 60°

From these observations it may be argued that the aforementioned groups correspond to two parental types whose bulk compositions were substantially different, but that the members of either type possessed rather close similarities with respect to their chemical constitution. Unless the latter qualification is made it is difficult to explain the limited variation in the optical properties of the plagioclase and the amphibole as observed in either group.

The third group, (*c*), a banded amphibolite, is of restricted occurrence and is found as an intermittent exposure over approximately 1500 yards on south Pella, where it attains a vertical thickness of 9 feet and dips

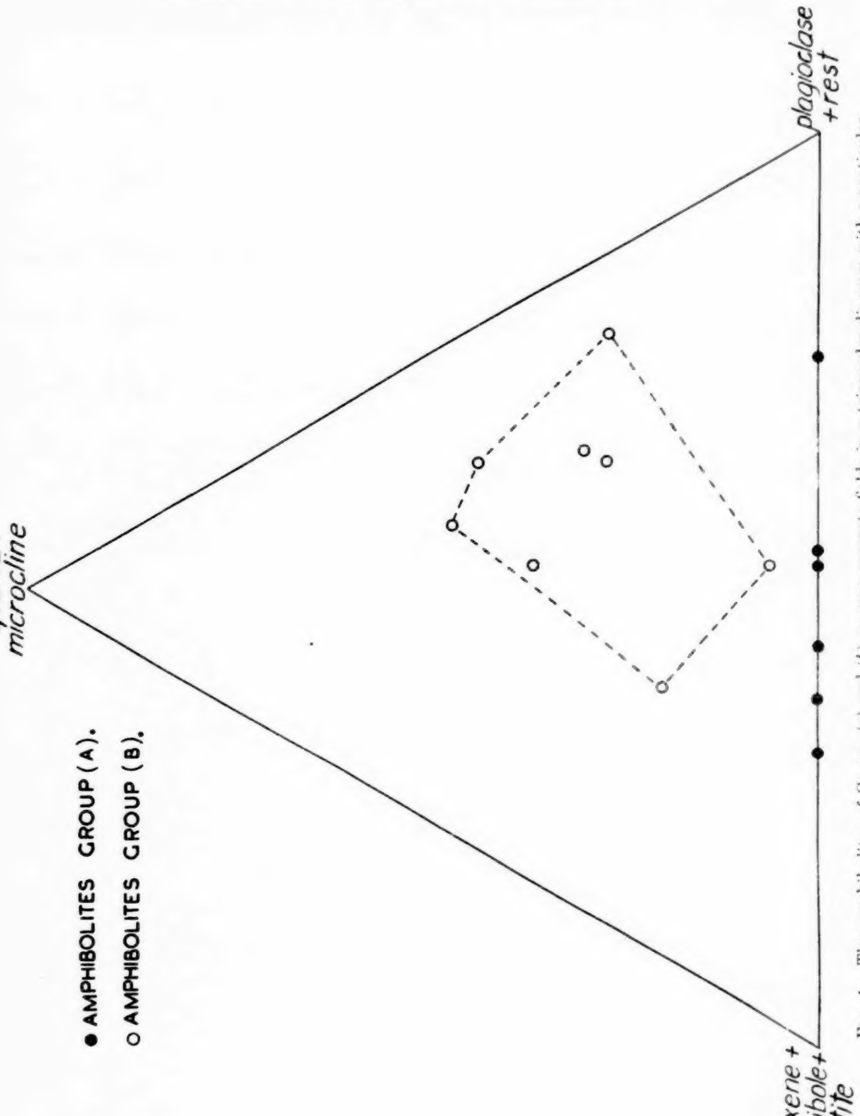

Fig. 4.—The amphibolites of Groups (*a*) and (*b*) assume separate fields in a triangular diagram with a particular combination of variables (modal percentages) at the corners.

25° to the north. The rock consists of an irregular succession of bands (varying from 0·5 to 5 inches in thickness) whose individual compositions are appended in Table IX.

This type is evidently analogous to the bedded amphibolite described by Mathias [20] from Zuurwater, 22·5 miles W. 24° S. of the above-mentioned locality, and the rocks undoubtedly belong to the same stratigraphic horizon, which was presumably of the nature of a varied calcareous clay.

Table IX.

The Bands of Group (c).

	(1).	(2).	(3).	(4).
Bytownite	..	9·5	..	56·3
Quartz	..	4·6	72·8	17·2
Amphibole	∓ 100	36·1	11·5	21·7
Pyroxene	..	49·6	14·2	..
Garnet	..	..	1·3	..
Rest	..	0·2	0·2	4·8

The last group, (*d*), occurs as small intercalations in the biotite gneiss at the base of the quartzites. The mode of a representative specimen gave:

$$\begin{aligned} \text{Amphibole} &= 61{\cdot}7 \\ Ab_{63}\,An_{37} &= 29{\cdot}4 \\ \text{Biotite} &= 7{\cdot}6 \\ \text{Rest} &= 1{\cdot}3 \end{aligned}$$

(c) *Chemical Analyses.*—The chemical analyses of the amphibolites (Table X), when compared with igneous rocks of similar acidities, endorse, by virtue of the excessive discrepancies shown by the other oxides, a sedimentary parentage. But, as indicated in fig. 5, this mode of origin is not confirmed by Osann's diagram, according to which the eruptives and the sediments (including para-derivatives) fall respectively to the right and left of the line AB.[18] Accepting a sedimentary parentage from the field relations and the aforementioned chemical evidence, this anomaly may be explained by either:

(1) The selective fixation by calcareous sediments of certain constituents which transfused from the granite—a mode of origin postulated by Adams [1] for some amphibolites of the Laurentian Area, Canada; or

TABLE X.

	I.	II.	III.
SiO_2	38·88	58·50	65·24
Al_2O_3	22·11	16·42	15·41
Fe_2O_3	4·88	3·74	1·10
FeO	4·99	3·52	2·92
MgO	7·91	2·70	1·56
CaO	16·00	5·50	7·70
Na_2O	1·93	4·95	1·83
K_2O	·26	2·87	2·64
MnO	·10	·12	·04
P_2O_5	·84	·36	·18
TiO_2	1·50	1·02	·58
H_2O+	·84	·46	·78
H_2O-	·10	·04	·10
Totals	100·34	100·20	100·08

Osann's Values.

	I.	II.	III.
Al	12·1	13·0	13·1
C	16·0	8·0	11·9
Alk	1·9	9·0	5·0

	IV.	V.	VI.
Al	11·4	29·9	11·0
C	18·1	0·0	15·8
Alk	0·5	0·1	3·2

I. Amphibolite lens, Pella, Anal. C. B. Coetzee. Mode, Table VI, No. 6.
II. Amphibolite on the Orange River, Zandfontein, Anal. C. B. Coetzee. Mode, Table VII, No. 4.
III. Migmatised amphibole-pyroxene gneiss, Klein Pella.[6] Mode, Table VII, No. 3.
IV. Anorthite-epidote-garnet hornfels, Klein Pella.[6] (Metamorphosed marl ?.)
V. Sillimanite-corundum rock, Pella.[6] (Metamorphosed "bauxite" ?.)
VI. Houston marl.[13]

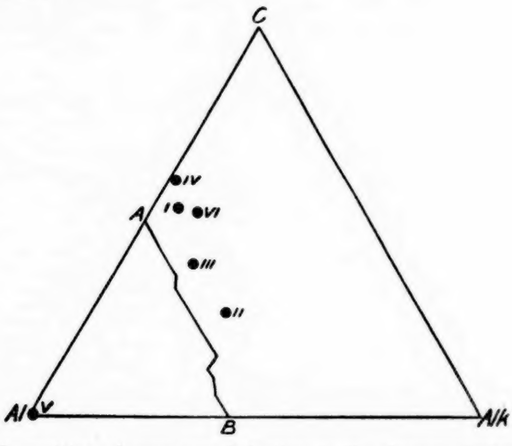

FIG. 5.—The positions of some para-derivatives in the diagram devised by Osann, according to whom the eruptives and the sediments fall to the right and left of the line AB respectively. The numbers correspond to the rocks in Table X.

(2) The inapplicability of the diagram to delineate para-metamorphics with low percentages of Al_2O_3, $K_2O + Na_2O$ and high percentages of CaO. The latter alternative is supported not only by the position of the Houston marl—a typical sedimentary rock which here falls in the igneous field—but also by the obvious fact that the position of the boundary AB is almost entirely dependent on the relative dominance of the molecular percentage of Al_2O_3. The latter condition, however, forms an exception rather than a rule for the lime-silicate rocks, although it is the case for many other types, *e.g.* shales, slates, ortho-gneisses.

In contrast to the biotite-gneisses the amphibolites do not generally lend themselves to injection and granitisation phenomena, which seems referable to their poorer fissility and to Bowen's principle [3] that "no saturated magma can dissolve inclusions of minerals belonging to an earlier stage of the reaction series." Reaction with the hornblende, presumably by the advent of potash-bearing solutions,[21] to precipitate biotite is sometimes exhibited by stringers of brown mica which traverse the amphiboles.

(e) *Correlation.*—If the correlation of the quartzites with the Kaaien Beds, which in the Upington-Marydale area represents a predominantly quartzose formation, is accepted, the amphibolites may be provisionally classified with the Marydale Beds. The latter comprise metamorphosed rocks of volcanic and sedimentary parentage, but since the original nature of the greater part is still obscure [23, 24] and corresponding amphibolites in the type locality are not represented on an effusive scale, there are no petrological grounds to stabilise the suggested correlation.

VI. General Conclusions.

The following points are now regarded as being established:—

1. The sillimanite-quartz nodules in the matrix of aplogranite originated by contamination with materials, identical with or similar to, the sillimanite-bearing rocks which occur in this area.

2. The sedimentary origin of the highly recrystallised quartzites of the Kaaien (?) Beds as suggested by field relations and laboratory evidence.

3. The progressive reconstitution of the biotite gneisses to an ultimate composition corresponding to that of the intruding granite-gneiss.

4. The dual composition of the parent sediment(s) from which the two dominant groups of plagioclase amphibolites have been derived.

5. The inapplicability of Osann's diagram to distinguish some calcareo-argillaceous rocks from normal eruptive types.

ACKNOWLEDGMENTS.

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EXPLANATION OF PLATE.

Fig. 1. Sillimanite-quartz nodules in a matrix of aplogranite. The dark rims are due to the concentration of biotite and muscovite. Reflected light × 1·4.

Fig. 2. Photomicrograph of a *single* quartz crystal showing the peculiar strain features described in the text. Crossed Nicols × 32.

Fig. 3. Band of Kaaien (?) Quartzite, 7–12 feet in vertical thickness folded into the granite, demonstrating the intrusive character of the latter into these re-crystallised sediments. The outcrops of the bands are indicated by the arrows.

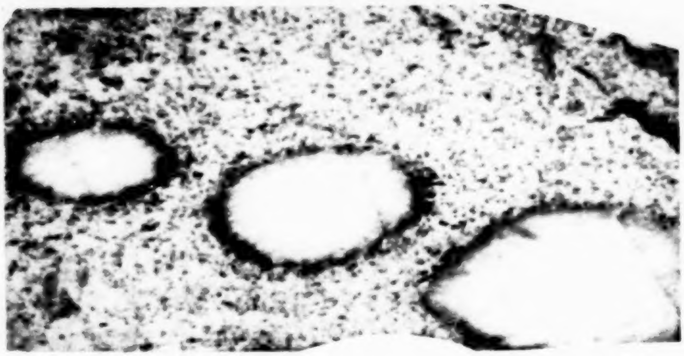


Fig. 1.

Fig. 2.

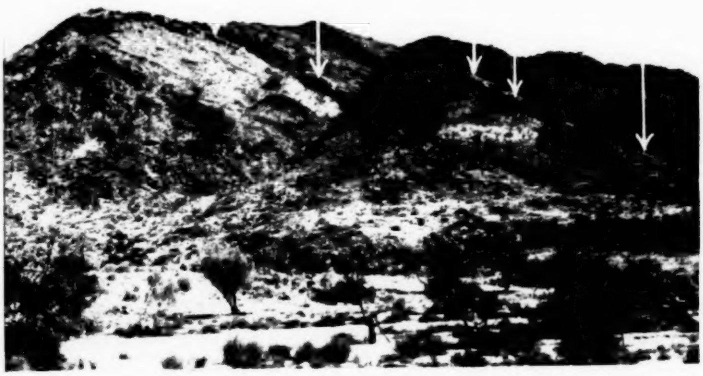


Fig. 3.

THE MIDDLE STONE AGE OF THE UPPER CALEDON RIVER VALLEY: THE MODDERPOORT CULTURE.

By B. D. Malan, Bureau of Archaeology, Johannesburg.

(With a Map and Plates VII–XIV.)

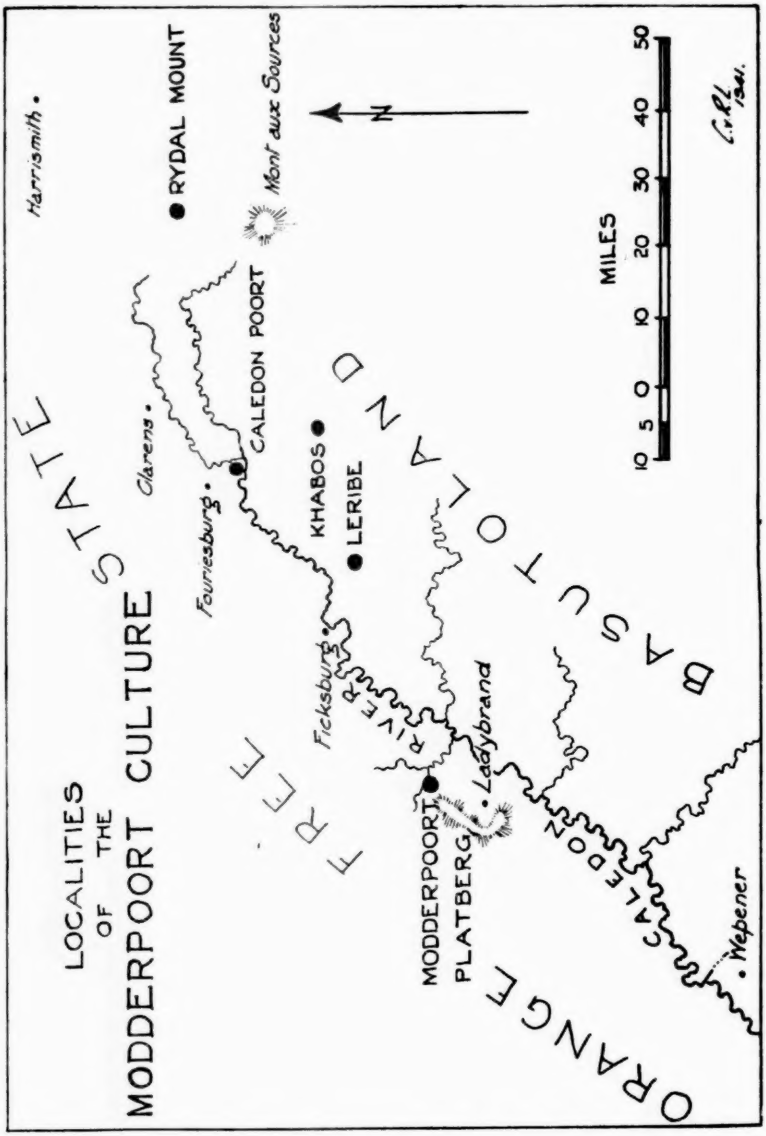
(Read April 16, 1941.)

CONTENTS.

Introduction.

In 1938 Mr. J. W. Eddolls, a teacher at Modderpoort, and Br. L. Robey submitted to the Bureau of Archaeology a collection of artifacts from a site near Modderpoort. Since then Mr. Eddolls has assiduously worked the site and built up a large collection which very adequately represents the industry of the site. The entire collection has been placed at the disposal of the writer, and a large and fully representative portion of it is now housed in the Museum of the Bureau of Archaeology in Johannesburg, while the remainder is in Mr. Eddols's possession at Modderpoort.

In addition, Dr. L. H. Wells of the Witwatersrand University Medical School has kindly placed at our disposal material which Mrs. E. M. Wells and he collected on a number of sites in the Upper Caledon Valley. These sites are situated at Caledon Poort, Clarens, and Rydal Mount in the Orange Free State, and at Leribe and Khabos in Basutoland (see Map). The collections from these sites represent the same phase of the Middle Stone Age as does the Modderpoort industry, a phase which was therefore practised over a very considerable area. From Modderpoort to Rydal Mount is a distance of almost 100 miles in a straight line, and there is no reason to suppose that the localities of these known sites indicate the limits of the area occupied by those who enjoyed this culture. Indeed, it is not too


LOCALITIES
OF THE
MODDERPOORT CULTURE
Harrismith
RYDAL MOUNT
Mont aux Sources
N
ORANGE FREE STATE
BASUTOLAND
CALEDON POORT
Clarens
Fouriesburg
KHABOS
LERIBE
Ficksburg
RIVER
CALEDON
Ladybrand
MODDERPOORT
PLATBERG
Wepener
MILES
10 5 0 10 20 30 40 50
C.v.R.L. 1941.

venturesome to suggest the probability that future discoveries will show that this culture characterises the upper reaches of most rivers draining westwards from the volcanics of the Drakensberg, *i.e.* rivers providing pebbles derived from the volcanics which, we shall see, formed the raw material of the great majority of artifacts.

Modderpoort.

The Site.

The writer visited the site in November 1940.

Immediately behind the mission station of the Society of the Sacred Mission at Modderpoort Station on the main line from Bloemfontein to Natal, the steep escarpment of the Platberg rises to a height of about 300 feet. A walk of some 2 miles in a south-easterly direction across the flat top of the Platberg brings one to several irregularly shaped eroded areas, on the surface of which the implements lie exposed by the erosion. The loose surface sand has been eroded to a depth of some 2 or 3 feet, leaving exposed a hard clayey surface derived from the underlying Cave Sandstone, which also appears as hard rock in a few places. The old land surface on and in which the implements occur is distinctly ferruginised. The occurrence of Middle Stone Age industries in association with ferruginised grits and sub-soils throughout South Africa and far beyond the northern borders of the Union has been commented on by Cooke (1941), and these represent the product of a distinct climatic break the precise significance of which is not yet clear. The largest eroded patch has a maximum length and width of about 100 yards, while another is approximately 150 yards by 75 yards. The floors of the eroded areas slope at approximately the same gentle angle as the surrounding uneroded mountain-top. The tendency at present is for the vegetation to reclaim and encroach on the sites, and I was informed loose sand-dunes of considerable dimensions were found there some twenty years ago. These have now disappeared, having been levelled and consolidated.

Materials.

The materials of which the artifacts are fashioned fall at a glance into two obvious groups. A number of implements are made from a fine-grained quartzitic sandstone of the Cave Sandstone group of sediments which occur in the neighbourhood; the remainder are cherts, agates, and chalcedonic materials which do not occur naturally on the site and must have been transported from some river draining the volcanics of the Drakensberg and sufficiently forceful to have carried pebbles for a considerable distance. The Caledon River itself is only 10 miles from the

site and is the only river in the vicinity which answers to these requirements. Despite careful investigation, there is no reason to dissociate the sandstone group from the chalcedonic groups of artifacts. The techniques employed on the different materials are identical, and the more weathered appearance of some specimens in sandstone is adequately explained by the comparative softness of the material. What differences there are between implements in the two groups are due to the different qualities of the materials rather than differences in technique. The two groups therefore, though differing somewhat in general appearance, belong to the same industry, which, with the exception of a number of twice-worked specimens on which we shall comment later, forms a homogeneous whole.

Mention should also be made of a few specimens in indurated shale, which occurs in the vicinity of the site. These are extremely weathered and deeply encrusted.

Technique.

The abundance of cores and factory-site debris as well as finished implements marks the site as "factory-and-home" and adequately reflects the technique employed. The site was occupied by people commanding a considerable facility with a very advanced Levallois technique. The presence of three varieties of struck and unstruck cores reveal a capacity for selection, and the preparation of different types of cores to yield flakes for different purposes. Specimens in sandstone only rarely show preparation of the striking platforms, probably owing to the comparatively coarse grain of the material. Some specimens in this softer material are also considerably weathered, and such fine work as the preparation of striking platforms and light secondary flaking on tools has in some cases disappeared. The harder chalcedonic specimens, on the other hand, consistently show careful preparation of striking platforms, except where suitable platforms are naturally provided by rounded pebble surfaces.

The specimens in sandstone are generally larger than those in the other materials. This is no doubt due to the fact that the chert and chalcedonic material was available only in the form of comparatively small pebbles, while sandstone was the only material available for large tools. The larger tools in the collection are derived from cores which must have been larger than any in the collection, probably because large cores after being struck were re-used until they no longer yielded satisfactory flakes. This absence of large cores, arising from economy of material, is not uncommon in Middle Stone Age assemblages and has been commented on elsewhere (1938).

The smaller cores have yielded many flakes which could only have resulted in implements so small as to be of microlithic size, but these tools

have not been discovered, possibly on account of their fragility and the greater likelihood of their being washed away, or becoming buried, or because they were removed for use elsewhere by their makers. Due allowance must be made for their absence.

The secondary trimming on tools is typical of an advanced "direct percussion" technique. The flaking is well controlled and results in straight even edges, while there is little evidence of unsuccessful work in the form of unwanted step-flaking. The secondary flakes are small and the flake-scars seldom extend far over the face of the tool. Although the scars are shallow and regular, they have not the very flat, "scaled" appearance associated with a pressure technique. It should be noted, however, that this is not true of secondary work on the flake-scar surfaces of tools; the reduction of bulbs of percussion and other work on the flake surfaces invariably is extremely shallow and it was done, if not by a pressure technique, then by some method which gave the same result. Widely spaced, bold secondary work, such as in the Still Bay and Mossel Bay industries result in serrated implements, is almost entirely absent. Small tools are in the majority, the general appearance of the collection being approximately of the size of the points illustrated in Pl. VIII, figs. 4 to 9.

Description of Artifacts.

(NOTE.—All artifacts described and illustrated are from the Modderpoort site.)

Cores.—Four types of cores occur.

(*a*) *Block Core yielding Parallel Flakes.*—Two cores of this type have been found, one of which is illustrated (Pl. VII, fig. 1). It is 6·3 cm. in length, 4·8 cm. wide, and 4·1 cm. thick. The striking platform shows no signs of preparation apart from the removal of two large flakes. The material is coarse sandstone, weathered soft. Several unsuccessful negative flake scars suggest the reason for its rejection.

(*b*) *Disc Cores* (Pl. VII, figs. 2, 3, 6).—These are flat cores, circular in plan, one face of which shows radial primary trimming from the perimeter inwards in the direction of the centre of this face. In struck specimens this face bears the negative scar of the final Levallois flake aimed at. The under face is trimmed round the perimeter only to the extent necessary to provide striking platforms for the primary trimming on the main face, and to control the size of the final flake. A few specimens tend towards the elliptical in plan. High-backed forms are strikingly absent. The term "tortoise core" has loosely been applied to a number of forms of Levallois core, and should, we feel, be confined strictly to cores which resemble the shape of the carapace of a tortoise, *i.e.* cores with high convex

backs and flat main faces, more or less elliptical in plan. Such forms are not found in the Modderpoort assemblage. Untrimmed portions of several specimens show the water-worn pebble source of the material. A few of the water-worn portions are faceted, showing that the material was derived from an older site, the nature and locality of which are unknown. The use of smooth pebbles rendered preparation of striking platforms unnecessary in some cases, but preparation of platforms occurs on the majority of specimens. Special mention must be made of a series of some half-dozen circular cores whose diameters are about 2 cm. They are very neatly made, and their resemblance to Magosian types is discussed later.

(*c*) *Triangular Cores* (Pl. VII, figs. 4, 5).—A number of these occur and bear the negative flake scars of convergent longitudinal primary trimming. Many of the points thus fashioned must have been considerably smaller than any which have been found. As in the case of the radially trimmed disc cores, one face often consists of an untrimmed pebble cortex or shows trimming round the perimeter only. Striking platforms are in many cases carefully prepared.

(*d*) A few small *Wilton-type* (*non-Levallois*) *Cores* yielding microlithic blades occur. Their significance is discussed below.

Flakes.—Parallel longitudinal primary flaking occurs, but is rare. Flakes in sandstone are generally thicker and larger than those in other materials. Typical Levallois flakes showing prepared platforms and radial negative primary flake-scars are common. A number of pointed flakes with convergent longtiudinal flake-scars occur, some of which must be regarded as finished implements not requiring secondary trimming (Pl. VIII, fig. 1).

Points.—These are derived from Levallois-type flakes and are generally slender, symmetrical and well-made, with prepared striking platforms in the majority of specimens. The majority show typical convergent longitudinal primary negative flake scars. A few showing no secondary trimming must be regarded as finished tools which required no further work after having been struck from their parent cores. The proportion of breadth to length varies considerably. The longest specimen measures 8·5 cm. in length and 3·4 cm. at its widest part (Pl. XII, fig. 1). The broadest specimen is 5·3 cm. long and 4·3 cm. wide at the butt, and is 1·2 cm. thick (Pl. VIII, fig. 3). The smallest point in the collection is 2·3 cm. long, 2·1 cm. broad at the butt, and 0·6 cm. at its greatest thickness. The remainder of the points range in size and proportions between these dimensions. Special mention should be made of a group, within this range, of small points, long in proportion to their maximum width at the butt. A typical specimen is 5 cm. long, 2·5 cm. wide, and has a maximum thickness of 1 cm. (Pl. VIII, fig. 5).

Points Worked on Flake Scar Surface.—The collection contains a number of specimens showing careful reduction of the bulb of percussion. The butts are trimmed to a point, while the edges are trimmed on the upper face in the same manner as the other points described above. The bulbs are reduced by "pressure" flaking from either edge of the tool. A number of points show very shallow reduction on the flake scar surface, sometimes accompanied by reduction of the bulb of percussion (Pl. IX, fig. 4). Although it would seem but a short technical step from this to the "laurel-leaf" lance-head of the Sill Bay culture, there is nothing to suggest that "laurel-leaf" types were made. The makers of the Modderpoort tools apparently were unable to execute secondary trimming which extended sufficiently far over the face of a tool to produce this form (Pl. IX, figs. 1, 3, 4; Pl. XII, fig. 2). The largest and best of these is 10·1 cm. long, 3 cm. wide at its maximum, and 1·3 cm. thick. It is triangular in cross-section and elaborately trimmed on the upper face round most of its perimeter (Pl. IX, fig. 1).

Points : Special Forms.—A few specimens of *pointes degagées* occur in which the tip of the point is formed by the removal of one large secondary trimming flake (Pl. VIII, figs, 7, 8). These may be left-handed or right-handed.

A single canoe-shaped double-ended point measures 6·8 cm. × 1·6 cm. × 0·9 cm. (Pl. IX, fig. 2). It is steeply trimmed along the whole length of both edges, and is trapezoidal in cross-section. The flake surface is untouched. The primary flake scars show the Levallois origin of the flake used.

The presence of two very carefully made curved points must be noted (Pl. XIII, figs. 6, 7).

Outils écaillés.—These form a numerous and important group of tools in the industry of the site. They occur with equal frequency on cores or on flakes. Often the cores and flakes show use as scrapers as well as *outils écaillés.* Both gouge (curved edge) and chisel (straight edge) types are present. As is to be expected, if the surmise is correct that these tools were used between a hammer and the object (in the manner of a carpenter's chisel), opposite edges of the *outils écaillés* often show bruising or flaking, and such use would also result in the roughly parallelogram shape which these implements commonly assume (Pl. X, figs. 1, 2, 3).

There are in the collection a number of utilised fragments which can conveniently be grouped with the *outils écaillés.* In these the characteristic damage occurs not along an edge, but at a point. The scaling from a point gives these artifacts somewhat the appearance of burins, but they appear to be essentially intermediary tools of the same order as *outils écaillés.*

Backed Blades.—Truncated flakes from Levallois cores have been trimmed to the crescentic form by means of steep secondary work at right angles to the main plane of the tool. With the exception of a small portion of one specimen, the "backing" is done in one direction only, *i.e.* across the thickness of the flake, using the flake surface as striking platform (Pl. X, figs. 5–9).

The ridges left by the primary flaking are present, and the tools are therefore not triangular in cross-section. In some cases portions of the arc of the crescent which are not sharp have not been backed, so that in several specimens only portions of the arc are trimmed. Two specimens show slightly everted ends. In a few cases the sharp chords of the specimens have been trimmed or show signs of damage through use. The largest of these is 3·6 cm. long, 1·5 cm. at its maximum breadth between chord and arc, and 0·3 cm. thick. The smallest is 1·9 cm. long, 0·9 cm. broad, and 0·2 cm. thick. This latter specimen is triangular in shape and, though not isoscelene in cross-section, is not unlike certain Wilton types (Pl. X, fig. 7).

A small series of crescent-shaped tools which have not been deliberately "backed" must nevertheless be included in this category. Advantage has been taken of crescentic flakes with blunt arcs which did not require "backing." Unlike the true "backed blades" the chords of these specimens have been carefully trimmed to a cutting edge. This group merges naturally into a group, not crescentic in form, with one blunt edge and one trimmed edge, which may be classified as side-scrapers.

Three specimens are of peculiar technical interest. Ovoid water-worn pebbles have been split, either intentionally or by natural forces. From the half-pebbles have been struck flakes which take the form of segments of a sphere, like the divisions of an orange * (Pl. X, fig. 4). The suitability of such blades for use as backed blades is immediately obvious. The cortex is smooth and requires no trimming to form the desired blunted back; the chords of two specimens have been carefully trimmed on the face which does not bear the bulb of percussion, while the chord of the third specimen is untouched.

It is of interest here to note that a collection of Middle Stone Age material collected by Mr. J. Harcus at the Kowie, and now housed in the Bureau of Archaeology, contains a complete series demonstrating this "pebble backed blade" technique. This series contains plain "quarter-orange" flakes, specimens with trimmed and utilised chords, specimens in which the backing provided by the pebble cortex has been improved by

* Mr. John Harcus of Johannesburg informs me that during recent experiments he obtained such "quarter-orange" flakes by a single blow on ovoid quartzite pebbles resting on a stone anvil.

flaking across the thickness of the implement in the manner of normal backed blades, and others, indistinguishable from normal backed blades, in which the whole of the cortex has been removed by such secondary backing.

Side-scrapers.—Under this heading may be grouped a large number of Levallois-type flakes which have been trimmed along one edge in typical side-scraper manner (Pl. XI, fig. 1; Pl. XIII, fig. 8). This is easily the most numerous group of tools in the industry. One exceptionally good specimen is trimmed on two edges and has a reduced bulb (Pl. XI, fig. 1). The selection of flakes for this purpose often appears to be extremely haphazard, great care in secondary trimming often being devoted to poor and unsymmetrical flakes. Consequently a miscellaneous variety of forms are included in this group, having in common only the feature of secondary trimming along one edge of a Levallois flake. The use of so many poor flakes in this manner suggests an economy of material, probably due to the distance which material derived from the volcanics of the Drakensberg had to be transported.

Burins.—A considerable number of burins are present. They occur both on flakes and on cores. The majority are single- or multiple-faceted ordinary ("*bec-de-flute*") types, in which the burin facets are backed against small negative flake-scars (Pl. XI, figs. 2–4). A few "angle" burins, with the burin facets backed against trimmed edges occur (Pl. XI, fig. 5). In one case a large redirecting flake in sandstone provided a suitable edge and has been used as a burin, though it was not deliberately shaped for the purpose (Pl. XI, fig. 6). One "ordinary" burin on a flake of cloudy quartz has also been trimmed along two edges as a scraper (Pl. XI, fig. 2), and one specimen on a core may be a double burin.

End-scrapers.—The following varieties of end-scrapers occur:—

1. Normal end-scrapers on Levallois flakes.
2. "Duckbill" types on non-Levallois flakes.
3. Broad end-scrapers, including concavo-convex forms.
4. Broad end-scrapers with reversed gouge cutting edges.
5. Planes or push-scrapers.

1. *Normal End-scrapers on Levallois Flakes.*—These are on approximately rectangular Levallois flakes, the straight edge opposite the striking platform being steeply trimmed to form a bevelled cutting-edge (Pl. XIV, figs. 1, 2; Pl. XII, fig. 4).

2. *Duckbill Types.*—These are too well known to require re-description, and are illustrated in Pl. XII, figs. 7, 9. One specimen is trimmed at both ends to form a double end-scraper (Pl. XII, fig. 8). While "Duckbills" do occur in some Middle Stone Age assemblages (*e.g.* the Hardy Collection

(Malan, 1938)), they are far more common in the Later Stone Age and are particularly abundant in the Smithfield "B" culture.

3. *Broad End-scrapers.*—These are on flakes which are broader than they are long, the broad edge being carefully trimmed (Pl. XIII, fig. 1; Pl. XIV, figs. 3, 4). When a large flake has been removed from the upper surface in the same direction as the blow which detached the tool from its core the resultant form is "concavo-convex" and, except for the preparation of the striking platform, is not unlike the "concavo-convex" scrapers of the Smithfield "A" culture.

4. "*Reversed Gouge*" *End-scrapers.*—These peculiar tools have not previously been described or seen in other assemblages. They occur on fragments of flakes which have plunged considerably, so that the flake scar is a concave surface (Pl. XIV, figs. 5, 6). They are trimmed along one of these concave edges in the manner of an end-scraper, but the trimming is characterised by marked "stepping." The working edge is the reverse of a modern carpenter's gouge, and the name "reversed gouge" end-scraper is suggested. Pl. XIV, fig. 6 shows two views and a section of a good specimen, which has also been used as a hollow srcaper.

5. *Planes or Push-scrapers.*—These are Levallois flakes showing at one end damage through use in the manner of a plane or push-scraper. These scars occur on the flake surface only; the upper face being trimmed as ordinary side-scrapers. The damage on the flake surface is not unlike that normally seen on *outils écaillés*, but the edges lack the battering typical of *outils écaillés* and the upper surface is undamaged (Pl. XIV, figs. 7, 8).

Circular Scrapers.—Only two specimens have been found. One is very thick (diameter 4 cm., greatest thickness 2 cm.), boldly and steeply trimmed; the material is a fragment of sandstone, stained a deep yellow and very weathered. The other approximates more to a rounded point, diameter 2 cm., thickness 0·6 cm., on a Levallois flake with prepared striking platform.

Hollow Scrapers.—Only a few hollow scrapers are included in the collection, and little care appears to have been employed in their manufacture. They occur on flakes or random fragments of rock (Pl. XII, fig. 6). The specimen illustrated in Pl. XII, fig. 3 is on a flake from a water-worn pebble and has been more carefully worked. It is the only specimen showing more than one notch.

Double-trimmed Side-scrapers.—Two interesting tools of this type are included in the collection. The larger of these is on a much rolled flake, the whole length of one edge of which has subsequently been re-trimmed on both faces, the intersecting negative flake scars of the secondary trimming forming a cutting edge (Pl. XII, fig. 5). The other is a small agate pebble

treated in the same manner, while another edge has been used in addition as an *outils écaillés*.

"Kasouga" Flakes.—Several flakes show shallow trimming or signs of use on the flake scar surfaces, and are reminiscent of the "Kasouga flakes" described by Dr. Hewitt (1933). They are, however, not true "Kasouga" types. The types described by Dr. Hewitt, and which occur in the Howieson's Poort variation and Wilton cultures near Grahamstown, are on thin slender flakes, and the secondary trimming on the flake scar surface often extends over the whole width of the flake. The specimens from Modderpoort are for the most part on heavier flakes, and the trimming extends only a short distance from the edge.

Serrated Scrapers.—The rareness of serrated scrapers is striking, only a few specimens having been found. Nearly all the secondary trimming consists of small flake scars so close to each other that the edges of the tools are straight. In a few specimens the secondary flakes are sufficiently widely spaced to form saw-edged or serrated srcapers. These are all on small blades, and there is no single example of the large serrated flakes which Goodwin (1928) has called "oak-leaf" types. The serrations are irregular. With one exception the secondary work appears on the upper surface of the flake; the exception is not unlike a serrated "Kasouga" flake and is illustrated (Pl. XIII, fig. 3).

Special Tools.—A few tools which do not fall into any type group require description.

Triangular Scraper.—A small fragment of a hinged flake has been very elaborately trimmed to a triangular shape. Although it resembles a tranchet in outline it cannot be classed as such (Pl. XIII, fig. 5).

Perçoir.—There is no true *perçoir* in the collection, but one tool approximates to this form. A Levallois flake with a broad "*chapeau-de-gendarme*" butt is trimmed to a sudden sharp point at the tip. Since, however, the secondary trimming is parallel to the ridges formed by the primary flake scars which control the shape of the tool, the resemblance to a *perçoir* is probably fortuitous (Pl. VIII, fig. 9).

Oblique Butt Scraper.—The butt of a Levallois flake has been extensively trimmed until it is oblique to the major axis of the flake (Pl. XIII, fig. 2). The angle between the butt and the major axis is approximately 60°. The trimming on the butt is steep and resembles the trimming on a backed blade. The use of the flake surface as striking platform for the secondary work and the removal of most of the bulb of percussion shows conclusively that the trimming was done after the removal of the flake from its parent core. Unfortunately the end of the tool remote from the butt has been snapped off at a recent date.

Butt-end Scrapers.—The oblique butt scraper and a few other specimens

in which the striking platforms show careful trimming, raise the question of butt-end scrapers discussed by the present writer in another publication (1938). This secondary work on the striking platform usually occurs opposite a concavity on the upper face of the flake. It is superimposed on ordinary primary preparation of the platform which renders it difficult of interpretation (Pl. XIII, fig. 4). Colonel Hardy believes that these are deliberately intentioned butt hollow scrapers, a view also held by Oakley and Mary Leakey (1937). One specimen on which exactly similar trimming has been done on the thickness of a small flake but not on the striking platform bears out this contention.

Numerical Analysis.

The following table is the result of a count of the specimens in the Modderpoort collection at the present time. The figures, naturally, have no absolute meaning for two obvious reasons. Further work on the site will add to them, and classification of some specimens is necessarily arbitrary, particularly in the case of broken tools. It is believed, however, that the proportions reflected by the table will be found to hold good, and the list brings out the wide variety of tools in the culture and the adequacy of the collection.

Cores:	Block	2
	Radial Levallois	58
	Triangular Levallois	9
	Wilton types	6
Points:	Convergent longitudinal, plain	18
	Convergent longitudinal, trimmed	90
	Other	63
	Reduced bulbs of percussion	10
	Flake surface trimmed	6
	Pointes degagées	2
	Curved points	3
Outils écaillés:	Straight or gouge edged	136
	Pointed	8
Backed blades:	Normal, chords plain	11
	Normal, chords trimmed	5
	Pseudo, trimmed	6
	Pebbles, chords trimmed	3
Side and Miscellaneous scrapers		295
Burins:	"Ordinary" (*bec-de-flute*)	13
	Angle	3
	Other	5

End-scrapers:	On Levallois flakes	6
	Duckbills	8
	Broad	7
	Reversed gouge	3
	Plane or push-scraper	4
Circular scrapers		2
Hollow scrapers		7
Scrapers worked on flake surface		17
Serrated scrapers		4
Core scrapers		15
"Nosed" scrapers		4
Triangular scrapers		1
Oblique butt scrapers		1
Butt-end scrapers		9
Double-trimmed side scrapers		2

Distribution.

The material found by Dr. Wells differs in no way from the industry of the Modderpoort site, though it must be noted that with one exception his are all surface sites. The scarcity of tools and comparative abundance of cores and flake fragments characterise the sites as "factory" and not "home" sites.

1. *Leribe.*—A small collection containing three cores, one used as a scraper and possibly also as an *outils écaillés*. A few scrapers and some flakes showing an advanced Levallois technique. The material is just sufficient to be identified with the Modderpoort culture.

2. *Khabos.*—One core scraper, one small flake scraper and a few fragments.

3. *Caledon Poort.*—This site yielded the largest of Dr. Wells's collections and contains a number of fine scrapers in agate and other chalcedonic material, as well as well-made cores in both chalcedonic material and quartzitic sandstone. Some fragments of large flakes demonstrate ability to apply the Levallois technique to larger material when available. The collection agrees in technique, degree of refinement, typology and *étât physique* with the Modderpoort collection.

4. *Clarens Town Lands, vicinity Municipal Reservoir.*—The collection is small, but there is sufficient evidence to identify the industry with the Modderpoort culture.

5. *Rydal Mount, Witzie's Hoek.*—This collection from an old land surface, though small, contains the best complete implements, including

points, side scrapers, butt-end scrapers, and a hollow scraper. There is no difference between this material and the Modderpoort collection.

Conclusions.

The industry of the Modderpoort site cannot be identified with any culture or variation hitherto described. The nearest described assemblages are from Mazelspoort (van Hoepen, 1932) and Vlakkraal (Malan, 1941), but the Modderpoort assemblage cannot be identified with the Mazelspoort Culture (*i.e.* van Hoepen's *Mosselbaaise Kultuur*) with which the Vlakkraal material is completely identified. Industries similar to that of the Modderpoort site are known to occur on five widely separated sites spread over a distance of 100 miles. It is very probable that similar industries will yet be found over a considerably larger area of the Orange Free State—Basutoland boundary districts. Consequently this must be regarded as a new culture within the Middle Stone Age group of cultures. The name Modderpoort Culture, after the type site described above, is suggested.

In the absence of stratigraphical evidence the relationship of the Modderpoort Culture to the other cultures of the Middle Stone Age cannot be determined. On typological and technical grounds it must be regarded as a very advanced expression of the Middle Stone Age.

The presence of a number of twice-worked specimens indicates either that some older Middle Stone Age site provided material which was adapted by the people who enjoyed this culture, or that the culture was practised on the site for so long a period that some tools or flakes became weathered and were later re-used, but the former is the more likely hypothesis. The presence of a few obviously water-worn specimens brought to the site but not re-worked confirm the former probability.

The small crescent and duckbill scrapers described above, a few very fresh small non-Levallois cores, and the abundance of *outils écaillés* hold out the tempting suggestion that we have here an approach to the Magosian culture (Burkitt, 1932) which, with its combination of advanced Levallois and microlithic forms, appears to represent a transition from the Middle to the Later Stone Age cultures. It should also be borne in mind that the smaller cores in the collection must have yielded a large number of tools which were so small as to be microlithic in character. If these had been found they would have altered the general appearance of the industry to a considerable extent. But the identification of the industry as Magosian on the strength of missing elements which we induce must have been present is obviously not justifiable, and since the few Later Stone Age elements present are equally well accounted for by the subsequent occupation of the area by Later Stone Age man, as evidenced by the occurrence

of rock paintings in the vicinity, the suggestion of Magosian affinities must be discarded. This is borne out by the fact that the Modderpoort material occurs on a lateritic horizon a few feet below the present surface, typical of Middle Stone Age occurrences throughout Southern Africa.

ACKNOWLEDGMENTS.

I am indebted to Mr. J. W. Eddolls for placing his collection at my disposal and for donating a great deal of material to the Bureau of Archaeology. He also accompanied me to the Modderpoort site on two occasions. My thanks are due to Dr. Lawrence Wells for giving me access to his collections, and to the Father-in-Charge of the Society of the Sacred Mission at Modderpoort and his colleagues for much kindness and generous hospitality.

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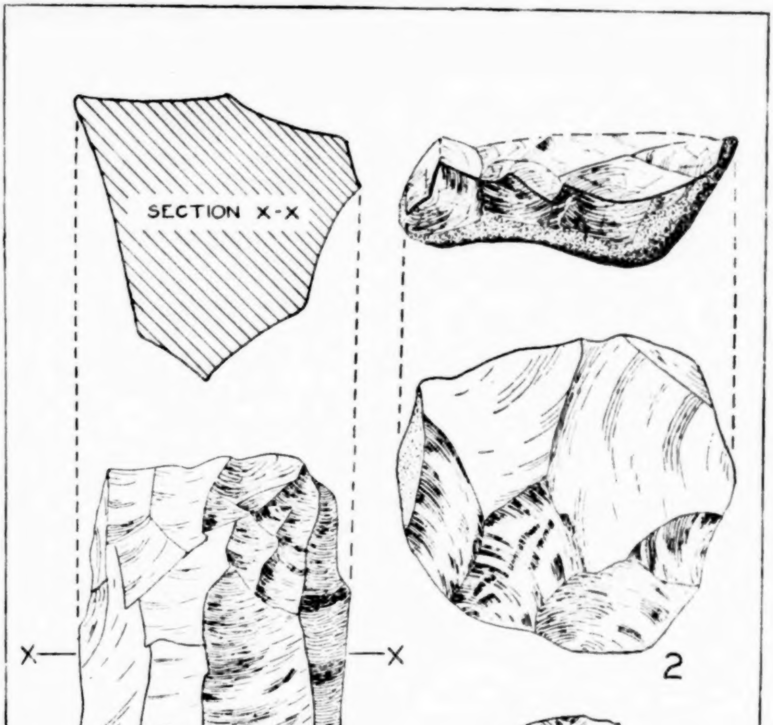

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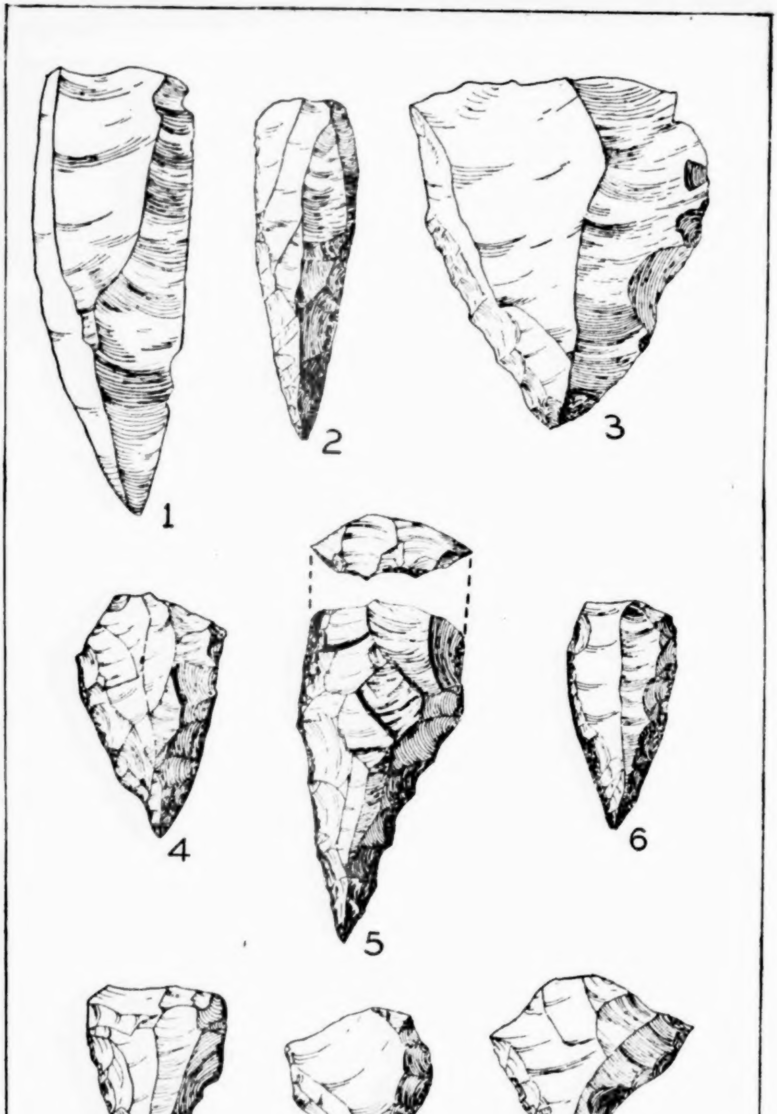

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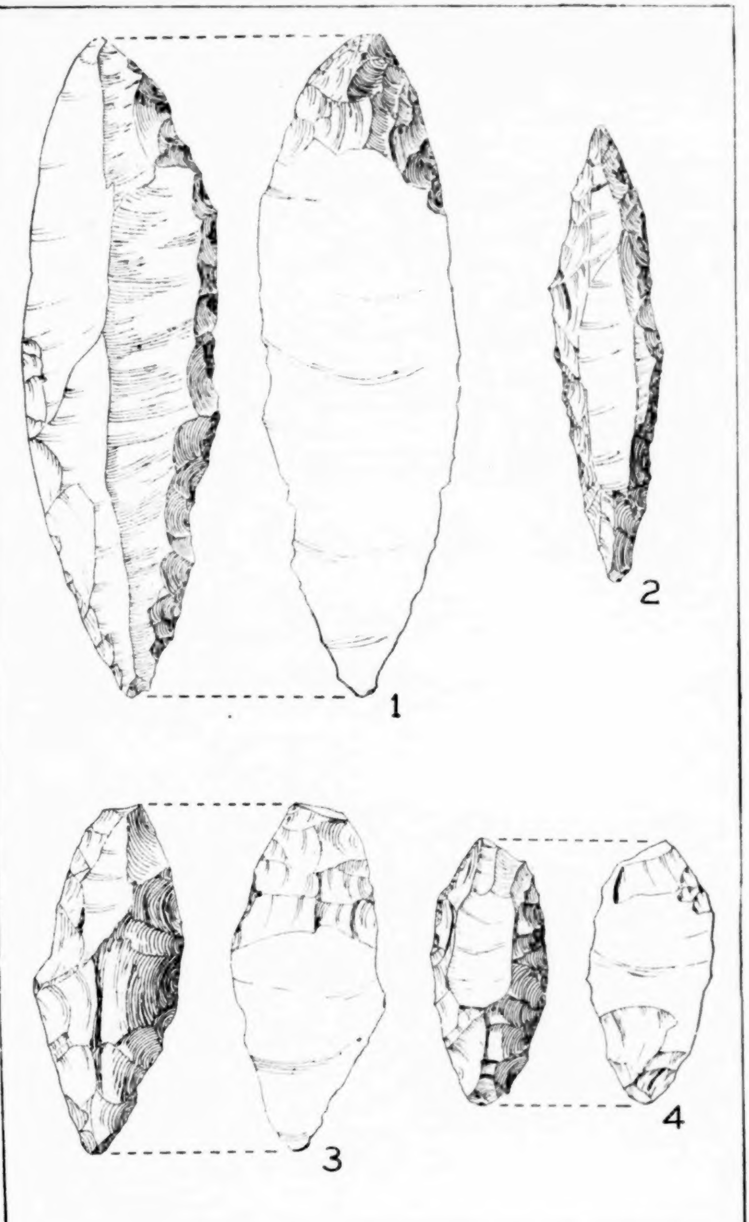

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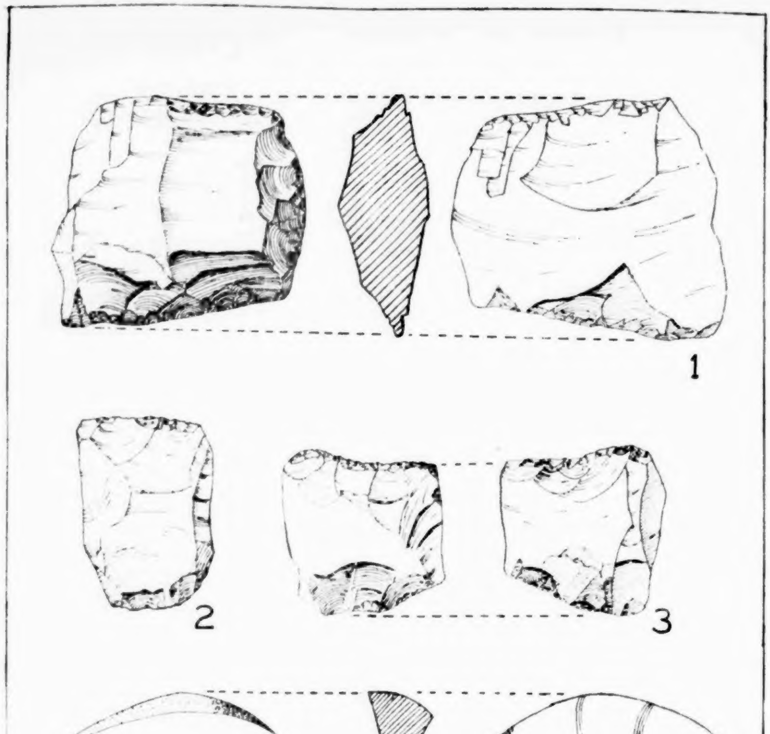

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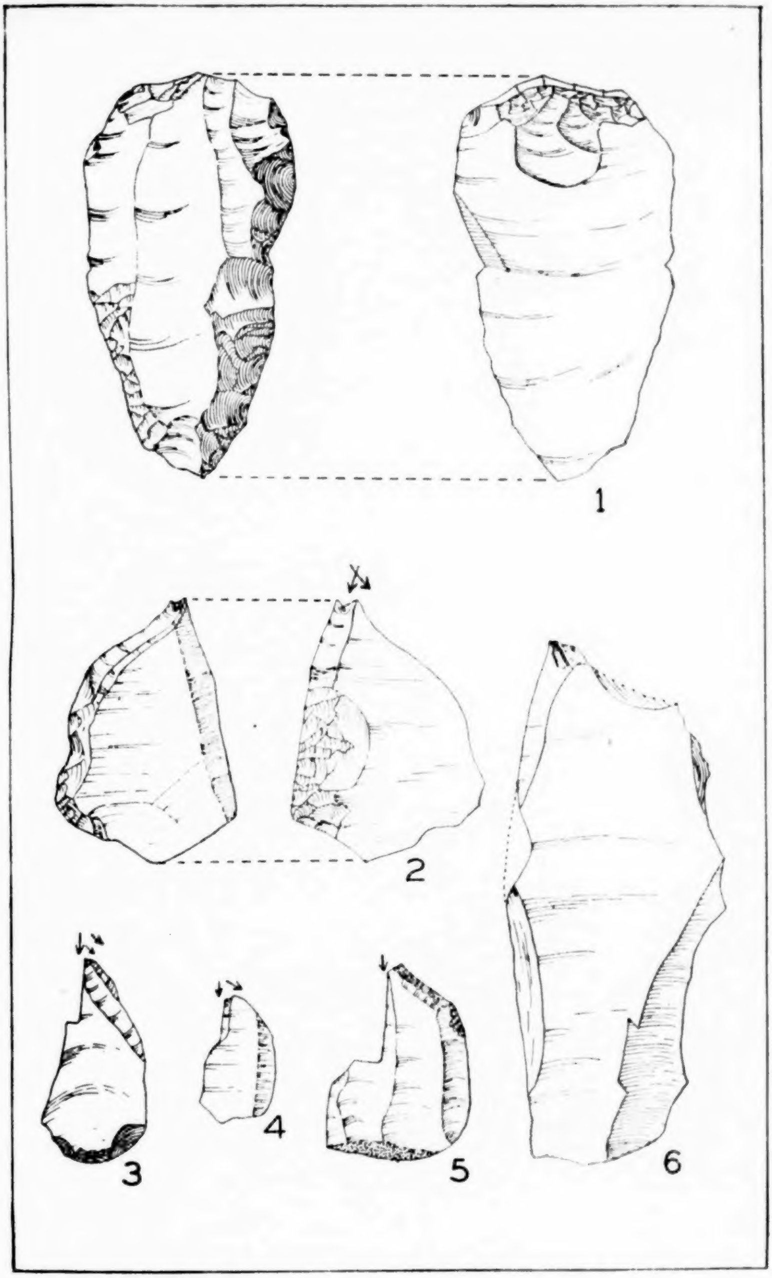

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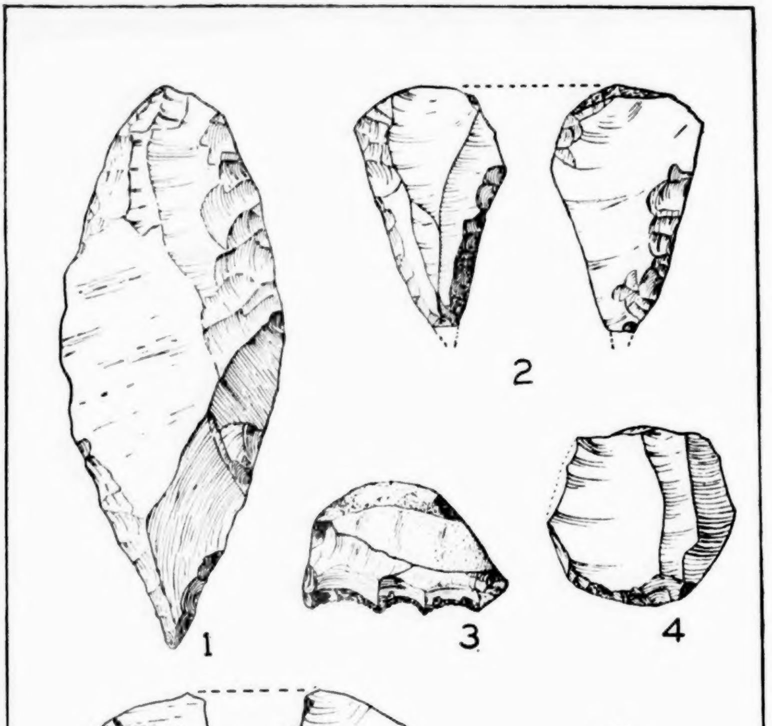

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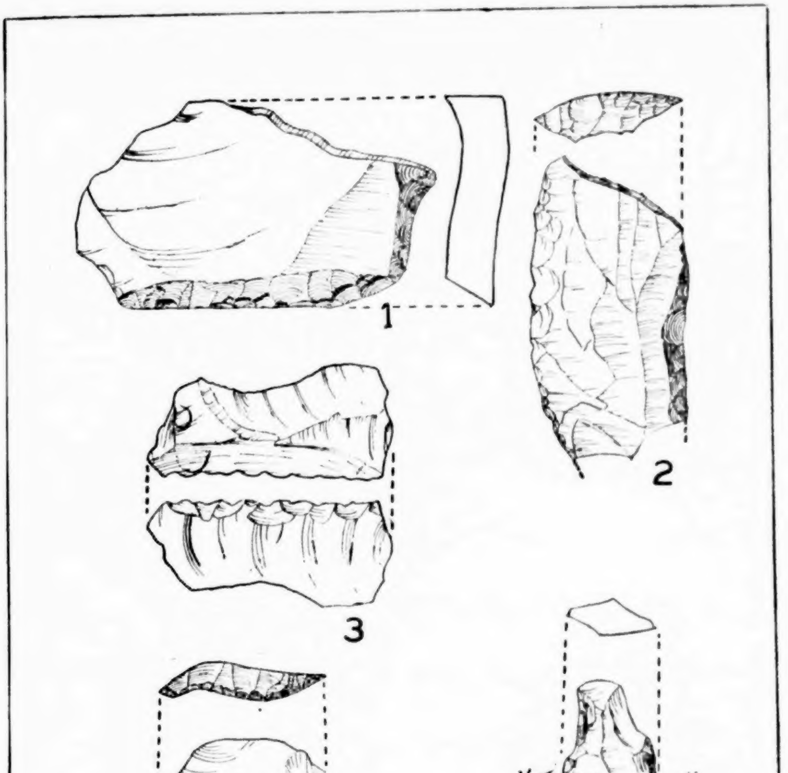

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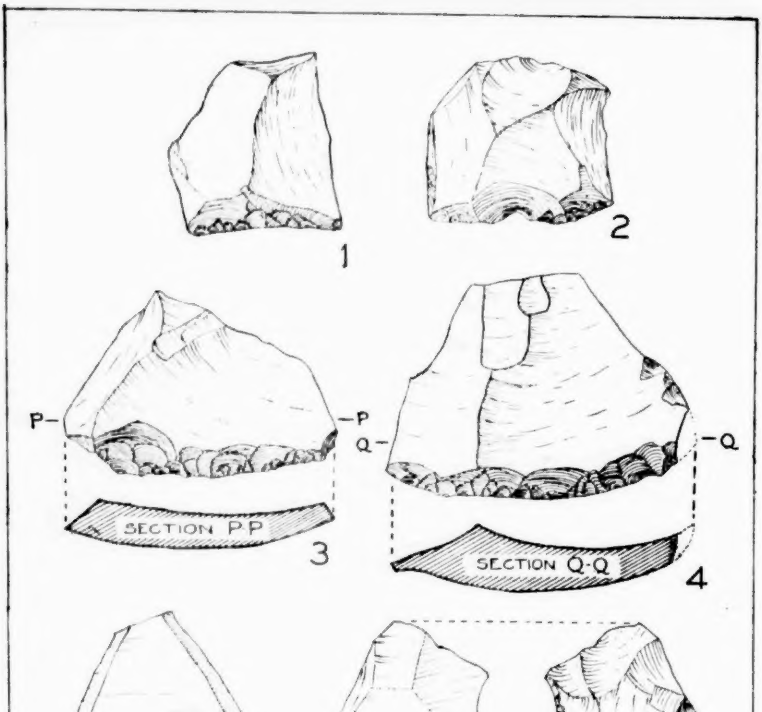

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MEAN YEARLY VALUES OF THE EARTH'S MAGNETIC FIELD AT THE MAGNETIC OBSERVATORY, CAPE TOWN.

(Latitude 33° 57′ S., Longitude 18° 28′ E.)

By A. Ogg.

(With two Text-figures.)

(Read August 20, 1941.)

This magnetic observatory was established in August 1932 to supply magnetic data to the International Commission for the Polar Year 1932–1933.

When the Polar Year work was completed, the International Association of Terrestrial Magnetism requested the Union Government to keep the observatory in operation for a further period because of the dearth of magnetic observatories in the southern hemisphere and because the Cape Town Observatory formed an important link in the chain of world observatories.

Owing to the magnetic disturbances created by electric railways it became necessary to remove the observatory from the neighbourhood of Cape Town. A new observatory (latitude 34° 25′·2 S., longitude 19° 13′·5 E.) has been established at Hermanus, Cape Province. The Cape Town Observatory was dismantled in January 1941 when a sufficient overlap of observations at the two observatories had been obtained to preserve continuity.

The publication of the reductions and analysis of the Cape Town observations from January 1, 1933, to January 1, 1941, which have been prepared by the staff of the observatory, has been deferred owing to the existing war conditions. It is, however, deemed advisable to publish a summary of mean yearly values, because of their general interest and importance.

The mean yearly values given in the following table are derived from the mean hourly values for all days of the year.

The graphs of these values show that the rate of decrease of the westerly declination appears to have reached a minimum value and is now increasing. The rate of decrease of the Horizontal Intensity, which has been one of the greatest in the world, is now diminishing; the rate of increase of the

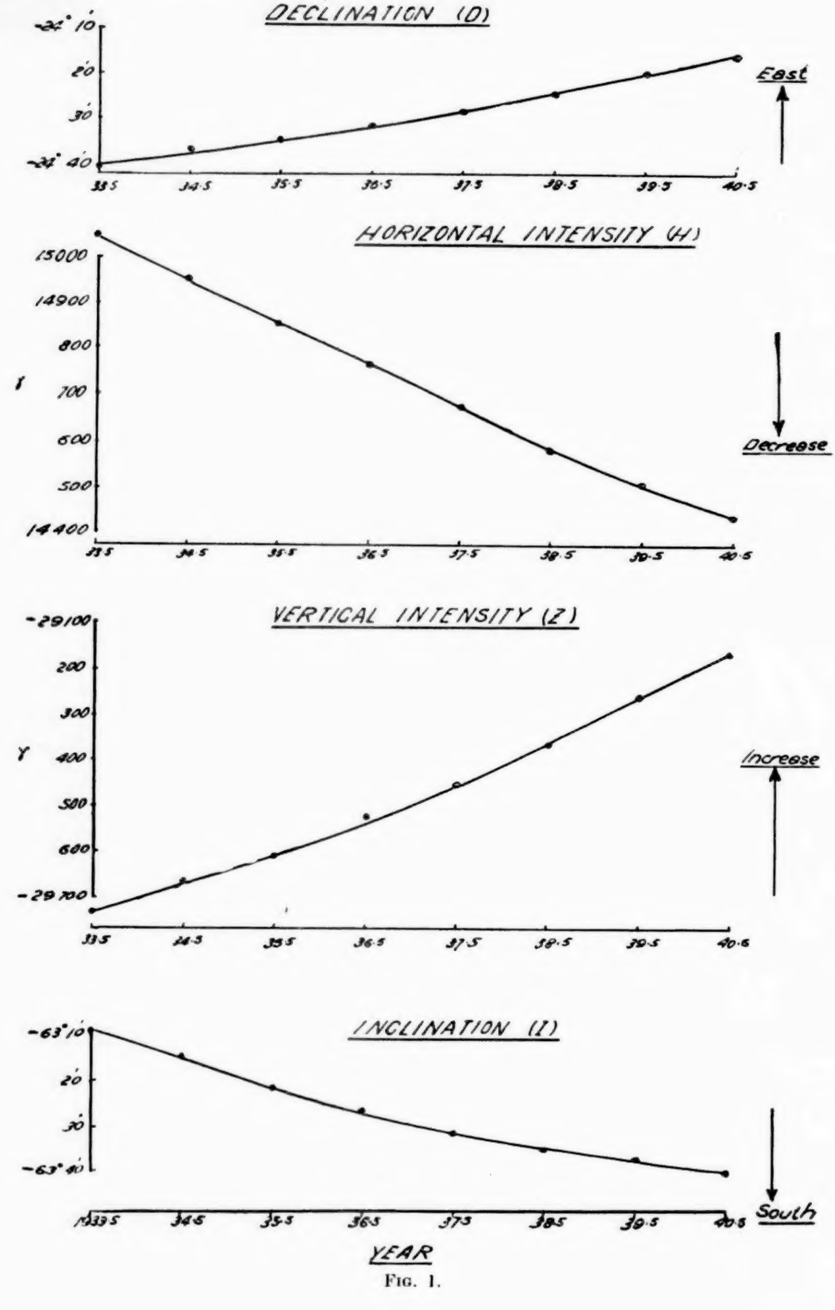
DECLINATION (D)
-24° 10′
20′
30′
-24° 40′
East
33·5
34·5
35·5
36·5
37·5
38·5
39·5
40·5
HORIZONTAL INTENSITY (H)
15000
14900
800
700
600
500
14400
γ
Decrease
VERTICAL INTENSITY (Z)
-29100
200
300
400
500
600
-29700
γ
Increase
INCLINATION (I)
-63° 10′
20′
30′
-63° 40′
South
1933·5
YEAR

FIG. 1.

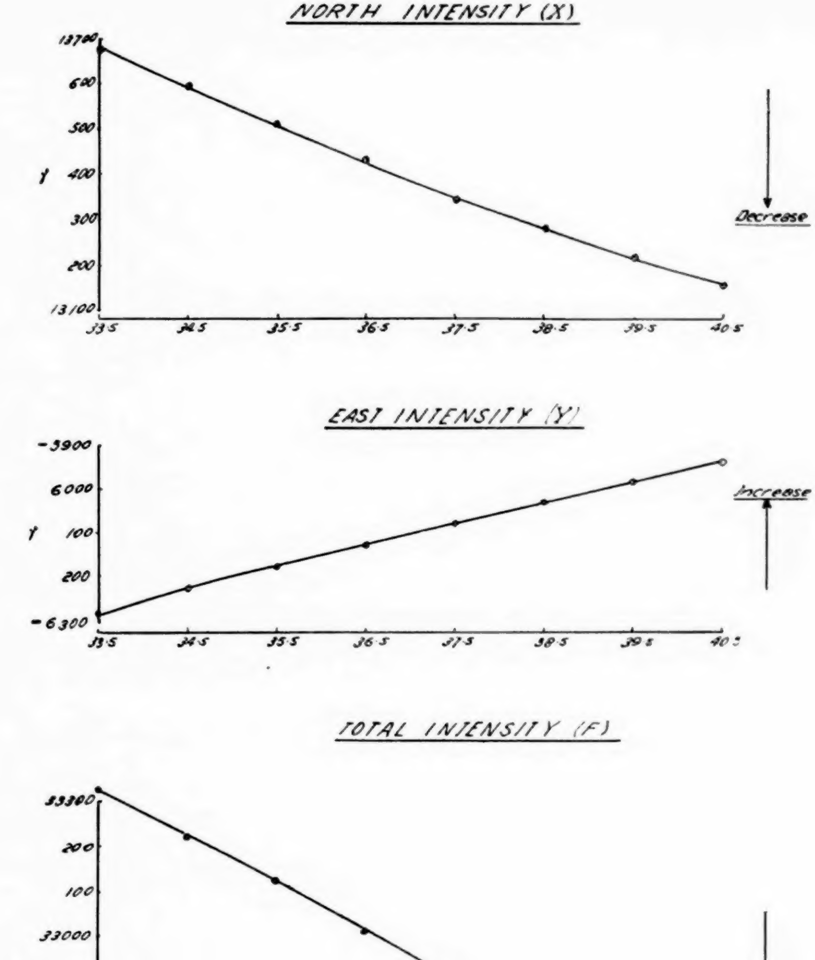
NORTH INTENSITY (X)
13700
600
500
400
300
200
13100
γ
Decrease
33·5
34·5
35·5
36·5
37·5
38·5
39·5
40·5
EAST INTENSITY (Y)
-5900
6000
100
200
-6300
γ
Increase
33·5
34·5
35·5
36·5
37·5
38·5
39·5
TOTAL INTENSITY (F)
33300
200
100
33000
32900
800
700
600
32500
γ
Decrease
1933·5
34·5
35·5
36·5
37·5
38·5
39·5
40·5
YEAR

Fig. 2

Vertical Intensity is increasing, and the rate of increase of the South Pole dip angle is diminishing.

MAGNETIC OBSERVATORY, CAPE TOWN.

Mean Yearly Values.

Year.	Declination West.	Horizontal Intensity	Vertical Intensity.	Inclination.	North Intensity.	West Intensity.	Total Intensity.
	° ′	γ	γ	° ′	γ	γ	γ
1933	24 39·9	15050	−29733	−63 09·2	13677	6281	33325
1934	24 36·7	14955	−29667	−63 14·9	13596	6228	33223
1935	24 34·5	14857	−29608	−63 21·2	13511	6179	33127
1936	24 31·2	14765	−29525	−63 25·9	13434	6128	33011
1937	24 28·2	14674	−29455	−63 31·1	13356	6079	32908
1938	24 24·4	14585	−29361	−63 35·0	13281	6026	32784
1939	24 19·8	14509	−29254	−63 37·2	13220	5980	32654
1940	24 16·0	14433	−29164	−63 40·2	13158	5932	32540

FURTHER EXCAVATIONS (1939) AT THE MUMBWA CAVES, NORTHERN RHODESIA.

By J. Desmond Clark.

(With Plates XV–XVII, seventeen Text-figures, and one Table.)

(Read October 16, 1940.)

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Introduction.

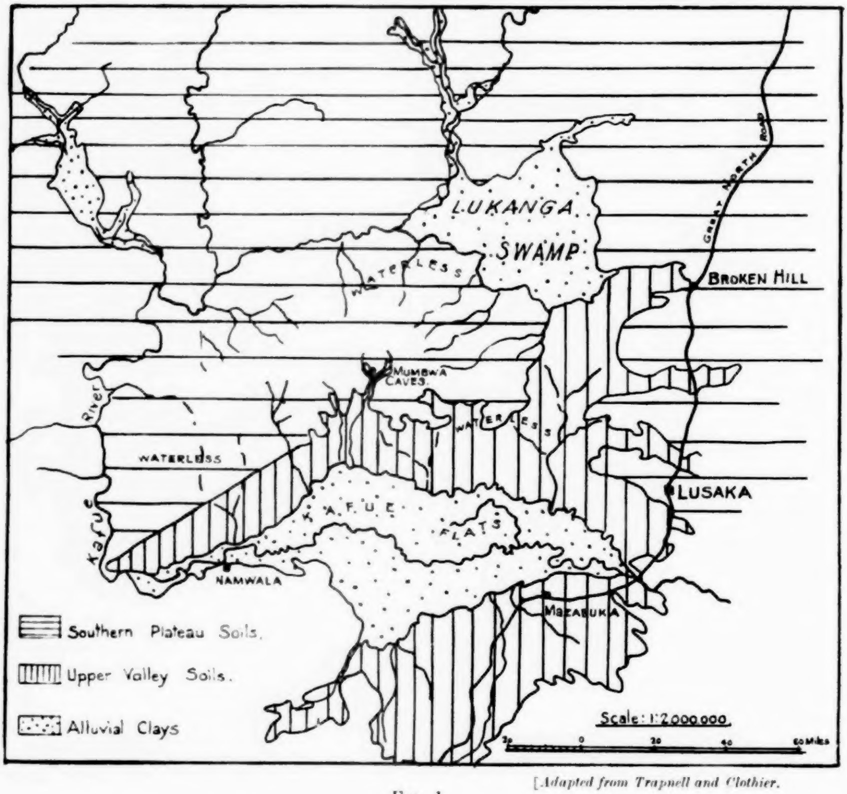
During the months of July and August 1939 I undertook, on behalf of the Rhodes-Livingstone Institute, a survey of some of the better known archaeological sites of the Lusaka district. Apart from a certain amount of Late Stone Age material on the fringes of the Kafue Flats little Stone Age material of any value or importance was found in this area, so that it was decided to proceed to Mumbwa. Our object was to obtain for the Museum a series of implements from the various deposits in these caves and also to discover if possible whether there was any cultural distinction between the Stone Age material in the black and red cave earths recorded by previous excavators. Our excavations revealed a number of interesting points not previously described, thus warranting a further publication on these, by now, well-known caves.

Situation, Geological and Ecological Notes (1).

The Mumbwa Caves are situated about 76 miles west of Chisamba, which lies 48 miles north of Lusaka on the railway line. The caves themselves

lie about 2 miles south-west of the Government Station at Mumbwa and to the left of the Mumbwa-Kasempa road.

Mumbwa is situated at the southern edge of the main plateau, and roughly in the middle of a district bounded on the north and west by the



[*Adapted from Trapnell and Clothier.*

FIG. 1.

hook of the Kafue River, on the east by the Lukanga swamp, and on the south by the flats of the Kafue, bordered by a rather ill-defined range of hills with no collective name. The mean average rainfall at Mumbwa is 30 to 33 inches, which falls mainly during the months from November to April. The climate is comparatively equable, mean maximum temperatures vary about 85° F. and mean minima lie between 60° and 55° F. Fig. 1 shows the three predominant soils with their respective types of vegetation, mapped and recorded by Mr. C. G. Trapnell for the Ecological

Survey—in the south the flood plain of the Kafue with its grassland, in the centre a narrow belt of the red Upper Valley Thorn soils, and over the rest of the area the relatively low-productive, wooded Southern Plateau soils.

The sole characteristic rendering this country habitable is the Kafue River, along which cluster the sparse African settlements in the district. The rivers flowing into the Kafue in the region under consideration show shallow, fertile valleys, for the most part dry throughout the cold season, but after rain becoming for a few hours rushing torrents. The Southern Plateau soils covering the greater part of the Mumbwa district are composed of from 50 to 60 per cent. of sand. They are buff or light in colour and of loose texture. Wherever sections of these soils were to be seen they showed a formation of ferruginous nodules in the lower levels in proximity to the underlying rotted rock. In road pits on the Mumbwa-Chisamba road these pale sandy soils, never more than two or three feet in thickness, charged with pisolitic ironstone nodules at the base, rest upon decomposed granite or limestone. No recognisable stone implements were recovered from these shallow deposits, but a few indeterminate flakes of quartz from the ironstone show an inclined unfaceted striking platform and typical bulb of percussion.

The correlation between vegetation and soil types is particularly close, the three main soil types each bearing distinct vegetative growth. That of the Southern Plateau soils is mainly medium woodland of *Isoberlinia paniculata*, often mixed with *Brachystegia* woodland with a sparse understorey composed of grass and scattered shrubs. The population over this area is from 2 to 4 per square mile. In the north-east, south of the Lukanga swamp, relict sand belts fringed with massive concretionary ironstone result in a flat monotonous mixed scrubland, large tracts of which are waterless and unpopulated.

In the centre and south the Southern Plateau soils give way to what are called the Upper Valley soils. These are found in lower lying regions of more modified topography, commonly occupying somewhat broken or gently rolling country with free drainage. These younger and colluvial soils are associated especially with limestone and mica schists. Their phosphate content is twice as great as those of the plateau and they give a greater degree of productivity. In colour those in the immediate vicinity of Mumbwa are a deep brownish red. They carry a very variable shrub woodland interspersed with tall grass; the chief tree growth in this district is Acacia. The population of the area varies considerably and is sometimes as much as 20 to 25 per square mile. This is the thickest area of native settlement.

Finally, there are the Kafue Flats—grassland formed on alluvial clays.

Trapnell suggests that warping of the land surface caused a temporary stoppage of the outlet of the Kafue, resulting in the deposition of these clays. At a later date the rock barrier at the eastern end was broken, resulting in the rejuvenation of the river system.

No thorough examination of these deposits was possible, but at one section the fossil tooth of a ruminant was discovered with fragments of a second.* A few quartz flakes and cores were also found, but of no very distinctive type. The deposits should yield important Stone Age material, but sections are extremely rare. These seasonally swampy clays lack tree growth and are of low productivity. The tall assegai grass is a common feature and in the dry season the country teems with game. Annual floods result in seasonal migrations among the cattle-owning Ba-Ila and Ba-Twa who inhabit the flats. The rest of the country is sparsely inhabited by the agricultural Ba-Luba and Ba-Kaonde in the north, south, and centre, and by the Ba-Lenje in the west.

The Boma at Mumbwa is built on the very edge of the Plateau soils at an altitude of 3910 feet; to the south of it the relief of the country falls very gently and the buff sands are replaced by the brownish red Upper Valley soil. On the very edge of this are situated the limestone bluffs where are the caves. A depression has here caused the red clay to be replaced by a shallow alluvial valley covered with tall grass. The dry beds of two small dongas meander through this, although apparently they only flow now for a short time during the rainy season. The difference in height between Mumbwa and the caves is roughly 100 feet.

I have thus shortly described the surrounding country as it gives some hint of the prevailing ecological conditions during the later phase of human occupation of the caves, and the significance of it will be discussed later.

Previous Excavations.

1925.—Mr. Farquhar B. Macrae, then District Commissioner at Mumbwa, excavated a trial trench in the entrance to Cave 1, and published a short account of his finds in "Nada" (2). This was the first archaeological excavation to be undertaken in Northern Rhodesia, with the exception of the blasting out of the skull of *Homo Rhodesiensis* from No. 2 Kopje at Broken Hill three years previously. To Macrae, therefore, we owe the discovery of the Mumbwa Caves and the first systematic collecting of Stone Age material from this territory.

Macrae carried his excavation down to a depth of 10 feet without reaching bed-rock. In the first foot he found evidence of recent habitation and small microlithic implements which he likened to the mesolithic

* *Connochoetes antiquus* Broom.

Azilian of south-western Europe. In the 8 feet of red earth below this he found implements like in appearance to the Solutrean laurel-leaf point, some attempts at burin production, a number of round stone balls and one *coup-de-poing*, which latter has given rise to the suggestion of the existence of a Stellenbosch or African Acheulian industry in the caves. The excavation was terminated after a layer of sterile red clay had been reached.

1930.—Five years later the Italian Scientific Expedition under Commander A. Gatti began excavations in the caves. The results of their work were subsequently published by Professor R. A. Dart and Signor N. del Grande (3). The deposits encountered in the upper levels were the same as those described by Macrae. In the uppermost foot of the black earth many fragments of pottery, together with three arrowheads, were found. Beneath this a 10-foot deposit of red earth was found to contain "Late Stone Age" implements. It is necessary to state that the authors used this term to include implements likened to the Fauresmith, Glen Gray, Stillbay, Smithfield, and Wilton cultures, and it seemed from this not unlikely that a cultural and stratigraphical succession of these industries was present. As there was little evidence of stratification within the thick deposit this was dug and treated as a cultural whole known as the "Quartz Stratum." In its top levels three polished celts and fragments of bored stones were found. Also within this deposit, besides various other skeletal remains, three tombs were found containing fragmentary remains of interments.

The main concern of this Expedition was the discovery of a reputed iron-smelting industry intercalated between two Stone Age strata. The presence of this deposit was betrayed by a discontinuous layer of "burnt ash" and "furnace slag," which also contained the base of the "furnace." No smelted iron or iron implements were found in the deposit, however, and analysis of the "slag" by Professor Stanley has shown it to be, not a slag, but a cave deposit of sand and silt cemented by calcium phosphate and carbonate. Professor Stanley considers the furnace to resemble a grave, an opinion with which the present author is in agreement, and it is concluded that from the evidence available in these caves the use of iron was confined only to the most superficial stratum containing the pottery.

Beneath this deposit, the "quartz stratum," was found the sterile red clay, 6 to 8 feet in thickness, in the upper foot of which an industry recognised by the authors as of "Mousterian facies" was found. At 17 feet from the surface the clay was replaced by a sandy, loamy, black earth resting on bed-rock.

A collection of flakes, implements, and animal remains was presented to the Institute's Museum by Commander Gatti, and from a study of these it appeared that implements assignable to at least two industries—the

Rhodesian Wilton and the Rhodesian Stillbay—were present. It was with these discoveries in mind that, for the reasons stated above, work was undertaken during July and August 1939.

REFERENCES.

(1) Trapnell, C. G., and Clothier, J. N. "The Soils, Vegetation, and Agricultural System of N. Western Rhodesia," Report of the Ecological Survey, Government Printer, Lusaka, 1937.

(2) Macrae, F. B. "The Stone Age in Northern Rhodesia," Nada, vol. i, No. 4, 1926.

(3) Dart, R. A., and del Grande, N. "The Ancient Iron Smelting Cavern at Mumbwa," Trans. Roy. Soc. S. Afr., vol. xix, pt. 4, 1931.

Part I.—The Excavation of the Caves, 1939.

Work was commenced on 20th July and continued without a break until 18th August. Camp was pitched on the "Boma" grounds through the courtesy of the District Commissioner, Mr. A. W. Bonfield, whose assistance and kindness materially contributed to the success of our undertaking.

It was possible to drive by car to within half a mile of the caves, and for the rest it was necessary to walk through tall grass growing on the red Upper Valley soil. Coming over the brow of the hill the first sight of the limestone bluffs in which the caves are situated was very impressive —these outcrops rise vertically in places, to a height of 70 to 80 feet, straight out of the gently sloping country around. A survey of the bluffs was carried out, three large caves and a number of small shelters being found. The two caves previously excavated lay in the northern outcrop, and two areas, one in each of these caves, were selected. The entrance of the third large cave in the northern rocks was left untouched. Excavation here would have necessitated removal of a considerable number of limestone blocks which had fallen across the entrance, thus making access a matter of difficulty.

An inspection of the sections exposed in previous excavations assisted us in determining the various cave deposits likely to be encountered.

The first area selected was in the entrance to Cave 1 (see fig. 2). The right side of the cave entrance had been previously excavated, so that a rectangular area 9 feet long by 5 feet broad was pegged out to the left of the main entrance.

The Italian Scientific Expedition's excavations had shown that settlement was restricted to the immediate entrance, and that the interior of the cave was devoid of implements and faunal remains other than an occasional stray flake or bone.

The selected area was dug in the form of a grid; the longer sides were

divided into four sections marked 1 to 4, while the shorter sides were divided into three sections and marked A to C. The grid was therefore subdivided into twelve sections, each 20 inches by 27 inches in area. The method of excavating this was to remove the earth from each section to a depth of 6 inches at a time, with the exception of the first foot. On account of the controversy regarding the age and stratification of the

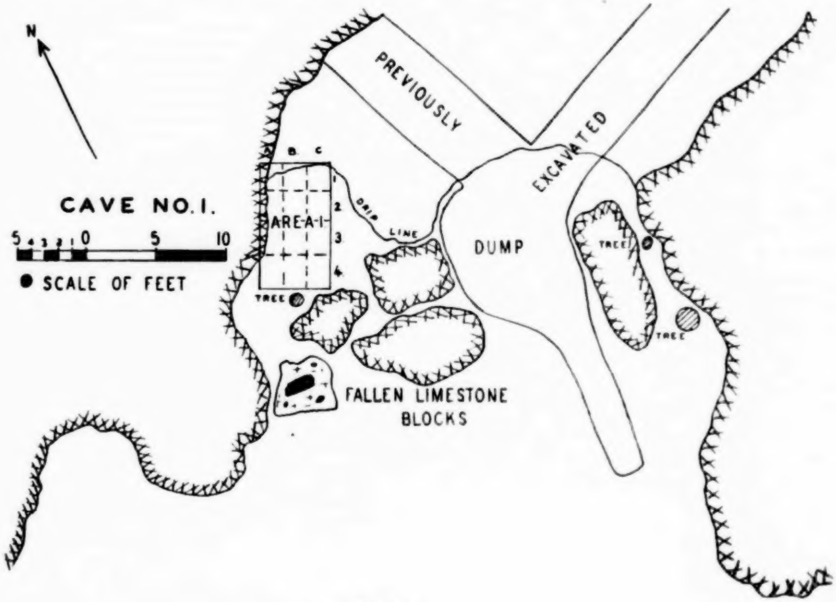


FIG. 2.

pottery the first foot was taken down 3 inches at a time, and we were thus able to fix more exactly the stratifical position of the potsherds. As each section was excavated, everything of interest was placed in a bag showing the section and level from which the material was derived. Back at camp the collections were washed and worthless material discarded. Finally every object retained was labelled in waterproof ink, so that it is possible to tell within a very limited area the exact position of each find.

All actual excavation was done by the author with the help of a trained African assistant, who sieved all earth and brought the contents for sorting. For help in excavating the sterile red clay a local Kaonde Native was engaged. Work was started at 8 o'clock in the morning and continued until 5 o'clock in the afternoon, with a short break in the middle of the

day for lunch. A bricklayer's trowel and an awl-shaped tool were the only implements used in excavating the black and red cave earths. In dealing with the calcareous red earth or "hardened complex" * and the sterile red "clay,"† however, it was necessary to use a geological hammer, with the addition of a pick and shovel for the sterile red clay.

Before rejection all earth was carefully sieved. For the first 3 feet a sieve with ⅛-inch mesh was used, but below the 3-foot level this became impracticable, and one of ¼-inch mesh was then employed.

The general appearance of the ground before excavation commenced is of interest. The cave mouth was littered with blocks of limestone, some of considerable size, which had apparently fallen from the cliffs above. They covered the black earth containing the Iron Age and Wilton industries. In addition, lumps of "hardened complex"—derived from the red earth—strewed the surface. Indeed there is every evidence to suggest that lumps of this material were thrown out by the makers of the Wilton industry in order to widen the space between the ground and the roof of the cave. At the entrance the roof was only about 2 feet above the ground-level, and work there necessitated crawling on hands and knees.

The limestone which composes the bluffs appears to have been subjected to considerable erosion by water-action, which would account for the formation of the caves and passages, but a certain amount of atmospheric erosion is also taking place to-day, and this causes the gradual wearing away of the exterior into small needle-like points which eventually entirely disintegrate.

Area I.

Previous Disturbance.—In this area very little, if any, disturbance was noticed. The burrowings of rock rabbits were entirely absent, and the roots encountered were comparatively small and had caused little disturbance. In this we were lucky, for a fairly thick tree was growing immediately to the south of our excavation, but its roots apparently grew in other directions. There was no evidence of white ants either, although on the red soil surrounding the caves traces of their presence were clearly seen. Such disturbance as existed was due in the main to water dripping from the cliff above. This effected a rough line, very clearly seen where the uppermost 3 inches of the black earth had been washed away and a miniature bed of quartz flakes and a few implements left exposed. The upper 6 inches of the deposit was found to contain a preponderance of rock rabbit bones, and it is possible that this should be regarded as some sign of their activity rather than as a delicacy of Iron Age diet.

* Term suggested by Dr. F. E. Zeuner (see Geological Report).

† For want of a better name this deposit has been termed a clay (see Geological Report).

Excavation.—The surface soil, where this had not been naturally removed—that is in sections A, B, C, 3 and 4—contained, besides humic matter, a few much-weathered fragments of the coarse comb-decorated pottery, together with some humanly fractured quartz flakes and four human teeth.

The top 6 inches of the deposit is composed of a black to dark brown earth which was fairly loosely compacted, and contained, in addition to many potsherds, fragments of iron tools and a few microlithic stone implements, lumps of burnt clay, and nodules of a cemented red earth with sometimes worked quartz cemented in it. At this level the potsherds and iron fragments decrease rapidly in numbers until at 9 inches to 1 foot from the surface they cease altogether except for two small sherds found below. In this area it was possible to distinguish in places a very thin sterile layer of black earth, only an inch or so thick, that separates the potsherds and iron tools from the underlying culture. At the 1-foot level and continuing to the base a marked change could be distinguished in the consistency of the black earth. Instead of being loose and friable it now took on a very much more compact appearance with, in places, what might be described as floors of small quartz pebbles, flakes, and implements. This compact black earth continued until the 2-foot-6-inch level was reached, when it merged into the underlying deposit of red cave earth which replaced it at the 3-foot level. It is within this compact black earth from 1 foot to 3 feet that the microlithic industry which we have called the Northern Rhodesian Wilton was found. Those implements and flakes found above the 1-foot level had been derived from below, due to disturbance of the floor during Iron Age times. All through this black earth were found slabs of limestone of various sizes, together with lumps of burnt clay and of the hardened complex and breccia: this latter is of importance, for whereas some of it may have come from fissures in the limestone cliffs and be probably of very early date, the greater part was in the form of nodules that had been broken off from a curious deposit at the right of the area which occupied most of sections B, C, 3 and 4. This deposit will be described in due course, but it may be stated now that the nodules within the black earth show conclusively that the whitish hardened complex was formed prior to the deposition of the black earth. The black earth itself, on drying, takes on a dark brownish colour and is composed of minute particles of sand, which appear to be wind-borne. It is interesting to note that within the cave this earth changes to a reddish earth of the same consistency. It seems probable, therefore, that only in areas that had been occupied or open to the deposition of humic material was the earth black in colour.

The microlithic tools tended to cluster in two patches in sections A

and B 4, and B and C 1. Nearly three-quarters of the Wilton tools found in this area came from these sections. Although a very careful watch was kept no shell beads or bone tools were recovered from the area. Animal bones were also very rare except in the first foot, and appear to have been destroyed through exposure before burial in the deposit was possible. The only faunal evidence recovered consisted of teeth, a large proportion of which were warthog molars. The bones within the first foot were mainly of small rodents. Charcoals were found scattered sporadically throughout the deposit—they were for the most part very fragmentary and it is, unfortunately, extremely unlikely that they could be identified.

The hardened complex was isolated and removed separately for it was found to contain a completely different industry. It was first encountered at from 3 to 6 inches from the surface, and it extended downwards in the shape of a truncated cone to the very base of the occupied deposits.

Microliths and other tools were abundant down to the 2-foot-6-inch level, when (in the blackish red earth) they became very rare. From the 2-foot-6-inch to 3-foot level a number of flakes were recovered, and waste material from the Wilton industry, as well as several flakes which appear to have been derived from below. This level (2 feet 6 inches to 3 feet) denotes the very base of the Wilton zone, and also, in the substitution of the red cave earth for the black, represents a break between two climatic phases. At this level also a very large limestone block had to be removed and the cave earth was charged with small lumps of quartz, quartzite, and sandstone.

In passing it is of interest to note that the Wilton industry was extremely homogeneous and that it was not possible to distinguish any evolution within the deposit containing these tools either in this or in the second area excavated. The larger backed blades are just as common at the top as at the base of the deposit and all microlithic forms are distributed evenly throughout. The polished axe found by our expedition came from a depth of 2 feet, and may therefore be of an intrusive nature; but I hope to show that I do not believe this to be the case.

From 3 to 7 feet the deposit is a red cave earth; compact where evidence of occupation is absent, but where it contains a quantity of factory debris, as immediately outside the cave roof, it is very loosely cemented. This earth contains an industry strikingly distinct from that found above. The flakes are larger, and a greater proportion show faceted platforms; the core forms are different; new types of implement occur not found in the Wilton industry. The industry approximates very closely to that known as Rhodesian Stillbay.

Occupation material was thickest farthest from the cave mouth, and was here nearly 1 foot deeper than at the entrance. Where the red earth

was sterile of occupation debris, however, it was of a consistency that rendered it almost impossible to distinguish from the sterile red clay on which it rests. This was most striking in the section exposed by the Italian Scientific Expedition. Here it appeared at first sight as if the red clay rose almost to the present floor-level, but on closer inspection it is possible to determine two earths, the upper levels—the red earth—containing occasional bone or worked quartz.

The red earth contained a greater proportion of ironstone, ferruginous quartzite, and hornstone than did the black earth, and these materials had been used in greater quantities for making implements. In view of the findings of the Italian Scientific Expedition we took great care in examining all Stillbay material in order to discover if possible any evolutionary development within the deposit. The fact that this industry was not as well represented here as we could have wished may have affected our impressions, but I think I may safely say that from the evidence available it was impossible to distinguish any appreciable evolution such as Armstrong found at Bambata. The only difference that we could see was that parallel flaking was commoner at the top of the deposit and that microlithic crescents did not occur in the lower levels. This negative evidence must be treated with caution, however, as pressure flaked points both bifaced and unifaced occurred throughout. Fig. 17, No. 1, is one from the 5-foot level, and fig. 17, No. 4, one from the 6-foot-6-inch level. Backed blades, burins, stone balls, and discs also occurred evenly distributed. Fig. 17, No. 13, is a backed blade from the 4-foot-6-inch level, and fig. 17, No. 14, one found at the 7-foot level. In section A 4, at a depth of 5 feet 6 inches, was a large limestone slab covering five phalanges and the fragments of a long bone of some large-sized ruminant. Apart from teeth, however, the faunal remains were not very plentiful. No human remains were found in the red cave earth.

Towards the base of the inhabited zone the red earth changed to a hard pinkish buff deposit, but continued in small pockets as far as the 7-foot level. The buff-coloured earth represents the splayed-out base of the hardened complex which gradually passes down into it. At depths varying from 6 feet 6 inches to 7 feet all evidence of occupation ceased and the underlying deposits were found to be sterile of bone or worked stone.

Now to turn to the hardened complex in the right side of the area. It was first encountered at a depth of 3 to 6 inches from the surface and extended down through the remaining 2 feet 6 inches of black earth into the red earth below. In both the areas excavated this deposit was seen to follow a drip line, which suggests that water dropping from the roof may have been responsible for its origin. In appearance it was yellowish and loosely cemented, and contained flakes and implements identical with those

found in the red cave earth although it protruded so far into the black earth. There was evidence to suggest, however, that this was an artificial mound formed by removing parts of the deposit from other places in order

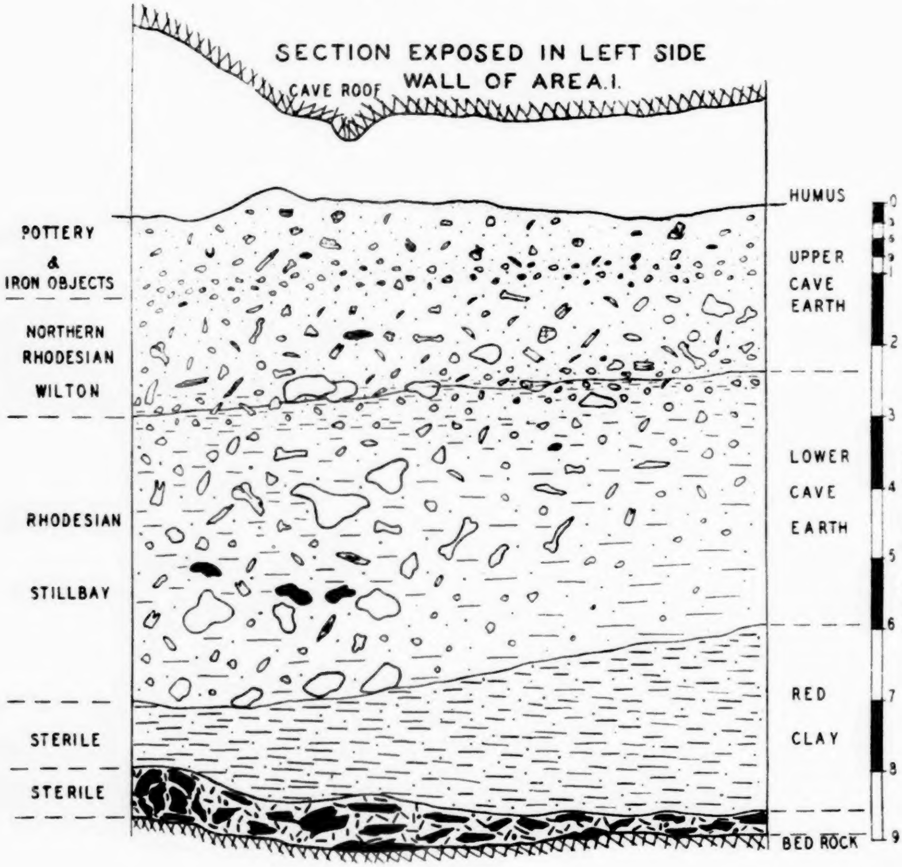


Fig. 3.

to widen the space between the floor and the roof by lowering the floor-level. The distinction between the flakes and implements from the hardened complex and those in the black earth is most clearly shown when they are seen thus side by side. The tortoise cores and large faceted flakes from the hardened complex are identical with the Stillbay industry recovered from the red earth, showing that the two were originally one

deposit, certain areas of which were cemented by water percolating through the earth. The "ash" and "burnt bone" areas of the Italian Expedition are other examples of this kind of deposit which was also encountered by

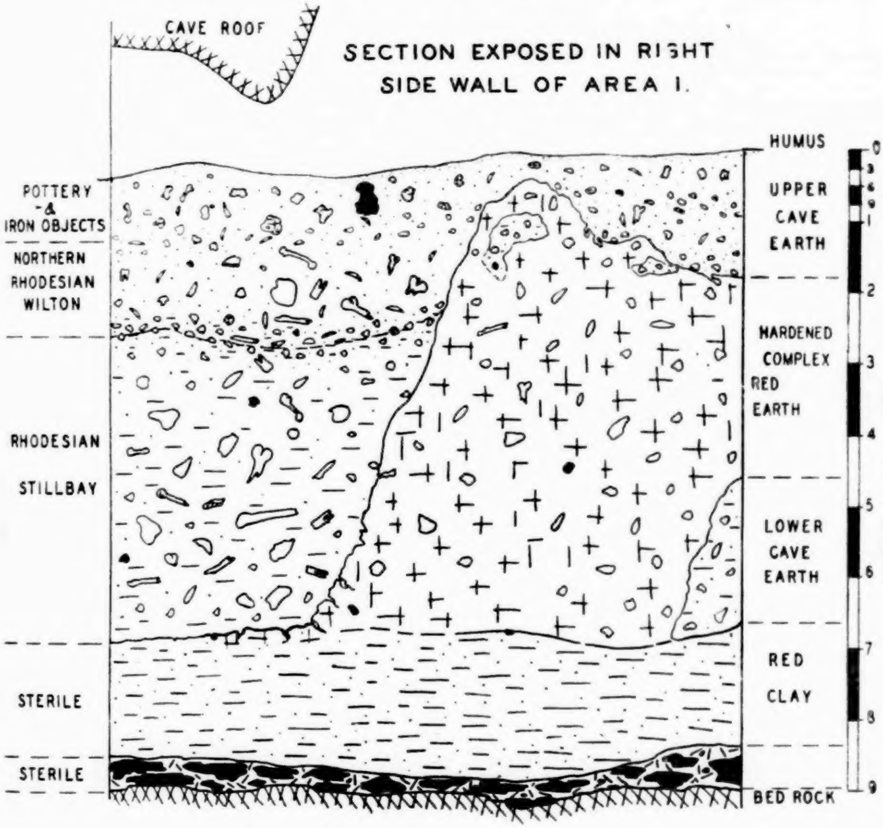


FIG. 4.

Macrae in his trial trench. Many of the implements from the upper levels of the deposit show a reddish-coloured, very thin patina, but in the lower levels this is not so commonly found. Bone was absent throughout. Where stone was absent the deposit forms a very much whiter and more compact mass excessively hard to remove, so much so that in section C 4 some of it was left as a means of access to the excavation. Towards the base, however, the deposit became softer and was composed of the

buff-coloured earth, later replaced by a sterile red clay on which the occupational deposits rest.

The red clay continues for a depth of 1 to 1½ feet, when it is replaced by a deposit of loosely cemented pisolitic nodules and black friable grains of some material, shown by Dr. Zeuner to be decomposed or metamorphosed rock. It was noticed that thin "skins" of this latter material surrounded greatly weathered lumps of blue limestone. The deposit was resting immediately on bed-rock at 9 feet 3 inches from the surface. It would seem to have been to fragments of this material when found in the upper deposits that the Italian Expedition gave the name of "furnace slag."

Apparently the reason for the shallowness of the red clay in this cave was the fact that the limestone floor, forming a kind of shelf, was much nearer the roof here, and thus precluded the accumulation of so much material as in Cave 2, where this "shelf" is absent.

Text-figs. 3 and 4 show the sections exposed in the right and left sides of this area.

Area II.

Having completed the excavation of Area I and reached bed-rock, a second area was selected—in the second cave, which is connected with the first by a long, narrow passage, and is now apparently inhabited solely by the porcupine. The area selected was to the right of the Italian Scientific Expedition's excavation and was a rectangle 9 by 5 feet with one short side abutting on the cave wall. It was chosen as near the entrance as possible as the occupied area had been found to be only in the actual cave mouth. It was divided into a grid, as was the first area, and similarly excavated (fig. 5).

Previous Disturbance.—A certain amount of shrinkage of the deposits was noticeable immediately next to the cave wall which might have caused a number of implements to fall down into deeper levels. It is possible that this is what had happened to certain potsherds found by the Italian Expedition at a depth below that at which sherds usually occur. In fact they state on page 388 of their report, "Very occasionally, however, pottery was also excavated at deeper levels, especially towards the side wall. . . ." This shrinkage did not affect our own excavation, however, due to the gradual slope up towards the wall of the hardened complex beneath.

We did find, however, that rock rabbits had been burrowing, and two of their tunnels occurred in sections B and C 3 and 4—but they had not materially disarranged the stratification.

Excavation.—Nearly all this area was beneath the cave roof, and thus the faunal and other remains were much better preserved. Here the black earth was found banked up against and resting on the hardened

complex and red earth, so that its depth varied from 6 inches to as much as 3 feet (text-fig. 6). It was found to be of the same consistency as in the first area, and to contain the same material. Potsherds and iron tools were found down to a depth of 9 inches to 1 foot at the end farthest from the cave wall. The surface soil contained a few sherds of a thin ware which appeared to be more recent in date than the coarse ware beneath.

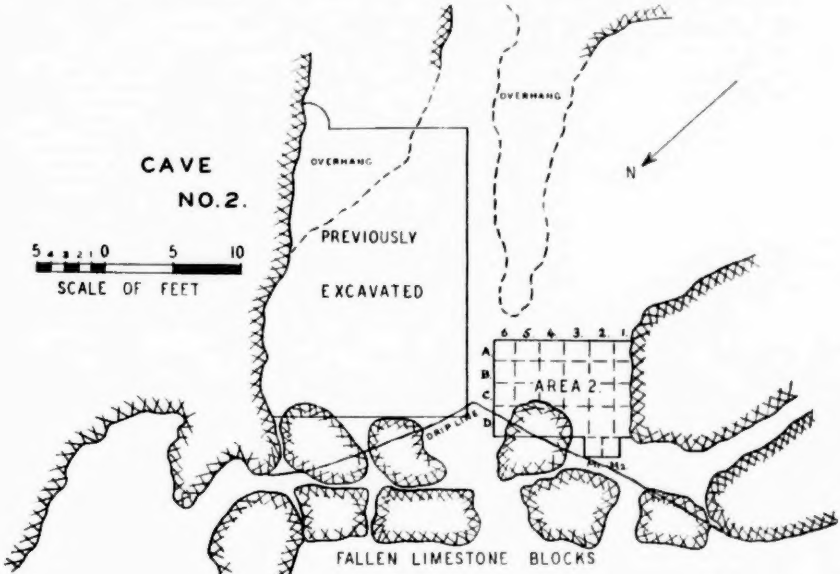


FIG. 5.

From 1 foot until the red earth was reached was found a wealth of material of the Wilton industry associated with a large quantity of faunal remains. As time did not permit of continuing the excavation to bed-rock we decided to concentrate upon the Wilton industry in the black earth, and the area was extended another 12 inches down the long side and 2 feet along the short side, giving a total area of 10 by 7 feet. Finally, a small extension 1 foot 6 inches by 2 feet 6 inches was made adjacent to sections D 1 and 2, where the implements were found to be thickest. A large block of limestone resting on the Wilton deposit filled the greater part of sections C, D 3, 4, and 5. In sections A, B, C, D 5 and 6 the implements and bones were often found coated with a very hard calcareous substance difficult to remove. In sections A and B 5 and 6 at the 1-foot-6-inch to 2-foot level we found three long limestone slabs end to end and appearing

to have been intentionally laid in position. They may possibly have formed part of a sequence which we had perforce to leave unexcavated.

Discussion.—In addition to a few minor considerations the results of our excavations differ from those of the Italian Expedition in that, firstly, no evidence of a "Mousterian" industry could be found in the upper levels of the red clay, and, secondly, we obtained no signs of an "Old Palaeolithic Industry" in the black gritty deposit resting on bed-rock.

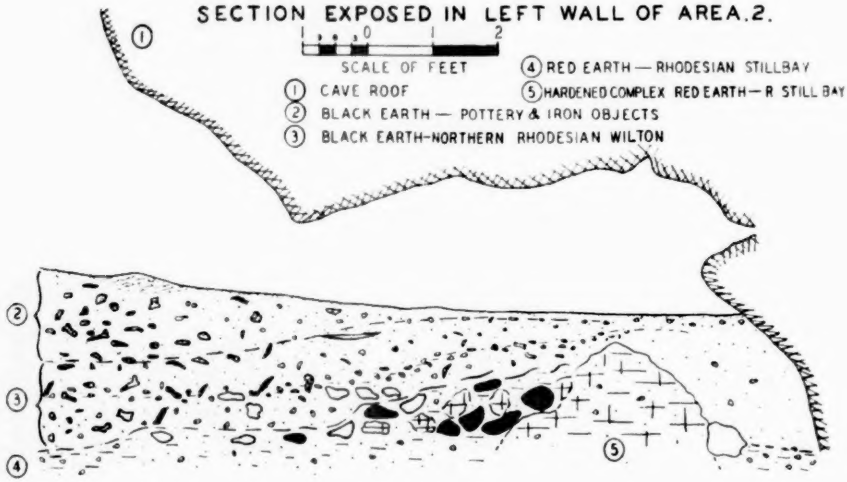


FIG. 6.

To turn firstly to the "Mousterian" of the red clay. This was apparently only found in the second cave, at the back immediately underlying the "furnace," and, as we found from an examination of sections left exposed by the Italian Expedition, was absent from the front of the cave, where the red cave earth was full of animal bones and worked stone and rested directly upon the red clay without any evidence of the "Mousterian." As has already been pointed out, where occupational debris is absent the red cave earth takes on a consistency almost identical with that of the sterile red clay, and this was found to be the case in the second cave just as in the first. If the section at the back of the cave containing the thin "Mousterian stratum" be examined three divisions are discernible. The topmost division consists of the black to red upper cave earth, the middle comprises the hardened complex and red lower cave earth, while the bottom contains sterile red clay. The factory debris composing the "Mousterian" seems to be simply the base, *i.e.* the original floor of the cave when first

inhabited by the makers of the Stillbay industry. The deposits slope very steeply from right to left, conforming to the slope of the roof and wall, and on the left where the cave floor meets the wall the "Mousterian stratum" is only 4 feet below the floor, the undulation of the deposit conforming to the contours of the red clay which forms a kind of dome towards the centre of the cave.

Regarding the cultural evidence, the "Mousterian" shows no divergence from the Stillbay. The flakes that I was able to procure from this horizon differed in no way from the other Stillbay types, moreover, there was no visible change in material. Some of the examples showed parallel flaking, and those illustrated in the Italian Expedition report, especially the finely made disc in fig. 11 on page 397, hardly argue for an earlier industry. It seems conclusive, therefore, that this thin line of debris at the back of the cave contains no earlier industry, and is merely the original floor of the Stillbay deposit into which it merges at the entrance to the cave.

Then there is the question of the "Old Palaeolithic" industry in the gritty black earth. As in Area I this deposit had proved to be sterile we endeavoured to examine the section exposed in the pit sunk by the Italian Expedition in Cave 2. Unfortunately, however, this had filled up for half its depth with earth that had collapsed from the wall of the section above, and we had no time to re-excavate it. It may be that in this cave the corresponding depôsit was distinct from the gritty black earth at the base of Cave 1. The fact that the Italian Expedition found fragments of bone, animal teeth, and some crudely fractured pieces of quartz and quartzite, would seem to be suggestive of definite occupation, although we ourselves were not fortunate enough to find any such evidence in the deposit at the base of Area I.

Part II.—Geology of the Sections in the Mumbwa Caves, Northern Rhodesia.

By Frederick E. Zeuner, London.

About forty samples kindly submitted by Mr. J. D. Clark were studied with the aid of explicit notes, photographs, cross-sections, and plans. Apart from the general problem of the climatic succession suggested by the deposits, two independent questions of particular interest were considered, namely (1) the nature of the material which Gatti, Dart, and del Grande believed to be furnace slag, and (2) the nature of a hardened complex associated with loose red earth, both containing Stillbay implements. A minor question was (3) the origin of a sterile layer of "red clay" beneath the Stillbay level. These points are dealt with in the

following lines, and the resulting suggestions as to the probable sequence of climatic fluctuations will be found under (4).

(1) *The "Slag."*

The chemical analysis carried out by Professor Stanley shows that this material cannot have come from a furnace and, for many sound reasons, cannot be a slag at all. He suggests that the material may be "simply a cave deposit of sand and silt cemented with calcium phosphate and carbonate." This comes very near the truth, though the "slag" cannot strictly be called a cave deposit. It is the product of disintegration of the natural rock.

The investigation of the samples showed that the structure of the blackish grey portions of the so-called slag is that of natural rock, with bedding planes and numerous minute healed cracks due to some sort of cleavage. The external appearance of a specimen much depends on the internal arrangement of bedding and cleavage, but it is obvious that all specimens were derived from the same original material.

This is most probably the limestone rock in which the caves are situated. Strictly speaking, however, it is not an ordinary limestone. In hydrochloric acid the fresh portions of the "slag" dissolve with a surprisingly quiet effervescence, though they do so completely in the course of time. Further, it is harder and heavier than ordinary limestone, and the chemical analysis revealed that not less than 26 per cent. of P_2O_5 are present. The rock of the "slag," therefore, appears to be a mixture of calcium phosphate and calcium carbonate, a so-called phosphorite.

As no specimen of the fresh bed-rock was available, it is impossible to say whether the latter too is a phosphatic rock rather than an ordinary limestone.

In the specimens of "slag" it is perfectly obvious that metasomatic processes have altered the original rock. Phosphatic zones now line the cracks and many of the bedding planes. Whether this was effected in the bed-rock before the cave was formed, or later, cannot be said with certainty, but the first suggestion is more probable.

The formation of the "slag" can be explained as a comparatively simple process of selective solution. The more carbonatic portions were dissolved first, whilst the more phosphatic portions resisted. This produced the cellular structure of much of the "slag." The interspaces retained the residue of the solution process, *i.e.* chiefly iron oxyhydrate, and sand, silt, and clay matter originally enclosed in the rock. The frequent blackish (instead of iron-brown) stain is due to the presence of oxide of manganese.

The process of disintegration took place chiefly in a horizon covering

the bed-rock. The black earth, in which the "slag" is embedded in this horizon, appears to be the same matter as the "slag" itself, only in a finely dispersed condition.

The question may be raised whether this process of solution could have been part of a process of soil-formation under the influence of atmospheric weathering. The thinness of the deposit (less than 9 inches) renders it unlikely that the surface of the black earth underneath the red clay was, at any time, a "land surface." Such questions cannot be decided without studying the section *in situ*, but I am inclined to think that the disintegration took place *after* the deposition of the red clay, and was caused by water percolating from higher levels.

It is obvious that lumps of rock, accidentally embedded in higher levels of the section, might have suffered a similar disintegration there. Pieces of "slag" found in higher levels, therefore, need not be derived from the black earth at the bottom of the section.

(2) *The Hardened Complex in the Red Earth.*

The hardened complex in the red earth containing the Stillbay industry is not a lime deposit. No effervescence takes place with hydrochloric acid, but the pieces disintegrate slowly, whilst iron goes into solution.

Under the microscope the material proves to be porous. The pores are not the result of loose deposition of the material, but have in many cases the shape of grains, or small inorganic or organic bodies, which must have gone into solution since the formation of this deposit. It is possible, therefore, that particles of calcium carbonate were present originally, but they have since disappeared.

The cement is partly iron oxyhydrate with some phosphate, partly almost pure phosphate.

The presence of the same cultural elements in the hardened complex as in the red earth suggests that they are practically contemporaneous formations. Most probably the formation of the hardened complex is connected with the drip line, as described in Mr. Clark's report (p. 143). The water which dripped down during the rains fell on the loose cave deposit (the red earth), which was mixed with cultural debris and burnt ash from fires (not furnaces, of course). Slow evaporation precipitated the phosphates and carbonates contained in the water. The absence of stalactites is due to the chiefly phosphatic nature of the solutions. Yet this hardened deposit appears to have formed a slight wall behind which dry deposition continued, though more slowly.

The fact that the hardened complex does not reach the surface and that the dark earth of the top level covers both the red earth and the

hardened wall, shows that a change in general conditions put an end to the formation of the hardened complex. The blackish upper cave earth contains an appreciable amount of humus. This perhaps indicates a change from seasonal rainfall to rainfall more equally distributed over the year, with denser vegetation. It is conceivable that under such conditions partial solution of the hardened complex was effected, carbonatic matter being removed whilst the phosphatic portions remained more or less intact. The result of this process, which requires permanent moisture in the soil, was the porous structure of the hardened complex.

(3) *The Red Clay.*

This sterile material is not a clay in the strict sense. It consists largely of floccules of iron oxyhydrate, small grains of quartz and other minerals, and little clay. It has a loose, dusty texture, quite unlike that of water-borne deposits, and resembles very much certain eolian deposits of terra rossa in caves of the Mediterranean region. There, wind carried the products of soil-formation into the caves, and a loose deposit of derivatives of the terra rossa mixed with some eolian sand was formed. The Mumbwa red clay is strikingly similar, though the red dust is more probably derived from lateritic soils.

A sample from the next higher layer, the red earth, of Mumbwa Cave I also appears to be eolian. It is reminiscent of a loess.

(4) *The Climatic Sequence.*

Four stages may be distinguished in the formation of the deposits composing the section:

(*a*) Decomposition of the bed-rock and formation of the "slag" layer with black earth.

(*b*) Deposition of the red clay.

(*c*) Deposition of the red cave earth and cementing of the hardened complex.

(*d*) Humous upper cave earth and partial disintegration of the hardened complex.

It has been said above (p. 151) that (*a*) may not have preceded (*b*). The decomposition of the bed-rock, therefore, should not be considered as a definite phase in the climatic sequence. It may have taken place before any of the higher deposits was laid down, or as late as during the formation of the upper cave earth.

The earliest definite climatic stage is the deposition of the "red clay," which probably marks a very dry eolian phase.

The phase of the Stillbay occupation and of the formation of the red

cave earth was damper than the preceding. Taking into account the light-red colour, the presence of what appears to be eolian dust, and on the other hand the cementation of some of the material beneath the drip line, the climate is likely to have been one with alternating dry and wet seasons.

During the Wilton more vegetation must have been present, and humus was produced in appreciable quantities. The soil must have been fairly damp throughout the year, and partial solution of the cement of the hardened complex took place, possibly under the influence of humic acids.

The top portion of the upper cave earth, containing the Iron Age, is not different from the lower portion in composition, but it is much looser according to Mr. Clark's report. Mr. Clark rightly suggests that this Iron Age level is the disturbed upper portion of the Wilton deposit. If this is so, then the climatic inferences drawn from the nature of the Wilton deposit need not apply to the Iron Age. This would have been a surface culture which disturbed the upper 9 inches of the Wilton deposit. The damp phase of the Wilton, therefore, need not have lasted into the Iron Age.

The climatic succession may be summarised as follows:—

Phase.	Climate.
Iron Age	?
Wilton	Damp throughout year.
Stillbay	Seasonally dry and wet.
Red Clay	Dry.

Part III.—The Cultures.

1. The Iron Age Culture.

By J. D. Clark and J. F. Schofield.

Pottery.

Considerable controversy has raged concerning the depth at which the pottery occurs and concerning its cultural significance. Dr. L. H. Wells has recently published in Man (1) an account of potsherds stated to come from the deeper levels and to be associated with a Late Stone Age industry; he considers this pottery to present certain resemblances to Miss Caton-Thompson's Class A pottery from Zimbabwe. He further states, however, that "the study of this material has convinced me that

there is no close relationship between Class A and the Mumbwa pottery such as Laidler (1938) has endeavoured to establish."

Mr. J. F. Schofield in a letter to Man (2) is in disagreement with many of the views expressed by Wells. His arguments, in which he considers the pottery to be associated not with a Stone Age, but with an Iron Age industry as represented in the uppermost foot of the deposit, need not be recapitulated here, but he claims that the sherds show close affinities with those from Gokomere, which he places, together with Caton-Thompson's Class A, in his R.1 category of pottery traditions in Southern Rhodesia.

Now our own excavations have shown that although there is no very pronounced stratigraphical break between the Iron Age and the Wilton industries, yet 99·4 per cent. of the pottery from Area I lies in the first foot of the deposit and 69 per cent. of the stone implements lie below this. In Area II 98 per cent. of the pottery lies above and 71 per cent. of the stone implements lie below the 1-foot level. As, therefore, there were no signs of any extensive disturbance, either natural or artificial, it can be stated with every degree of certainty that the pottery is associated with the iron tools found, and is not an integral part of the underlying stone culture. Should any further proof be needed it is supplied by Dr. Broom's analysis of the faunal remains from this level which has yielded remains of the ox and also of the domestic dog (see Appendix II). It is necessary to note, however, that four fragments of pottery have been found below the 1-foot level—two in Area I and two in Area II. In the first area one sherd was found in the 1-foot-6-inch to 2-foot level and one very small fragment was recovered at 2 feet 3 inches from the surface. The two sherds found in Area II come from a depth of 1 foot 6 inches and both belong to the same pot, one being a rim sherd; the pot is undecorated. None of these sherds show any decoration, but the clay and firing differ in no way whatsoever from the rest and they are of R.1 type. We are fortunate in our assessment of this culture in having for comparison a number of sherds that were presented to this Museum by Commander Gatti in 1930. As no doubt can now exist as to their stratigraphical position we illustrate several of these sherds which show variations in form and decoration not found amongst those recovered during our own excavation.

In view of the fact that no climatic break is discernible between the levels containing these two cultures it is reasonable to suppose that they followed fairly swiftly the one upon the other, and that these few sherds from the top of the Wilton stratum denote contact between the two cultures during the declining phases of the Wilton. Evidence for this is substantiated by finds in the Zambesi Valley, where in several cases

Northern Rhodesian Wilton sites have yielded sherds of Class R.1 type pottery. Corroborative evidence is provided by the Salisbury Commonage (3) and Nyazongo Rock Shelter sites in Southern Rhodesia (4). It seems, therefore, that these Wilton folk were a pottery-using but not a pottery-making people.

A description of each sherd illustrated will be found by the side of figs. 7, 8, 9, so that it only remains to state here very briefly the general characteristics of the collection.

Clay and Firing.—The majority of the sherds show a coarsely mixed clay with many angular fragments of quartz and haematite—an intimation probably that the pots were made locally and not brought from a distance. The method of production was on the coil principle, and several sherds show fracture along the junction of imperfectly joined coils.

Firing varies very considerably. Some pots are comparatively well fired, while in others the clay is extremely friable and very ready to crumble. The surface layers, however, are usually more cohesive.

In colour the core of the clay varies from a light grey to black, but brown and red are also, more rarely, found.

Both the outer and often the inner surface of the sherds are finished in colours ranging from deep grey through brown to red. Both the surfaces have been smoothed and apparently burnished, but in the case of many it is not possible, on account of weathering, to tell if burnishing has been carried out or not. A few of the sherds, however, usually those from large-sized pots, have the interior left in a comparatively roughened state with often large lumps of quartz protruding, in a similar manner to the second and third century Roman Mortaria in Britain.

The thickness of the pots varies between 16 mm. and 7 mm., the average being 10 mm.

Decoration.—Decoration is almost invariably over the neck and shoulder, more rarely on the rim. It is produced by two main techniques, a stylus or stamp and by direct incision—all decoration was cut or stamped on to the wet clay before firing. No fragment of polychrome pottery or sherd with graphite finish was found.

Of the two types the stamp decoration is by far the commoner, and was produced in a number of different ways.

(*a*) With a stylus or pointed stick, thus forming cuneiform (8, 3), rectangular (7, 10), or triangular impressions. An example of the last was found among the pottery presented to this Institute by the Gatti Expedition. A smaller fragment from the same pot is illustrated by Wells (1, Pl. E, fig. C).

(*b*) Birdbone impression—one sherd (7, 13) appears to show a small band of decoration executed by this method.

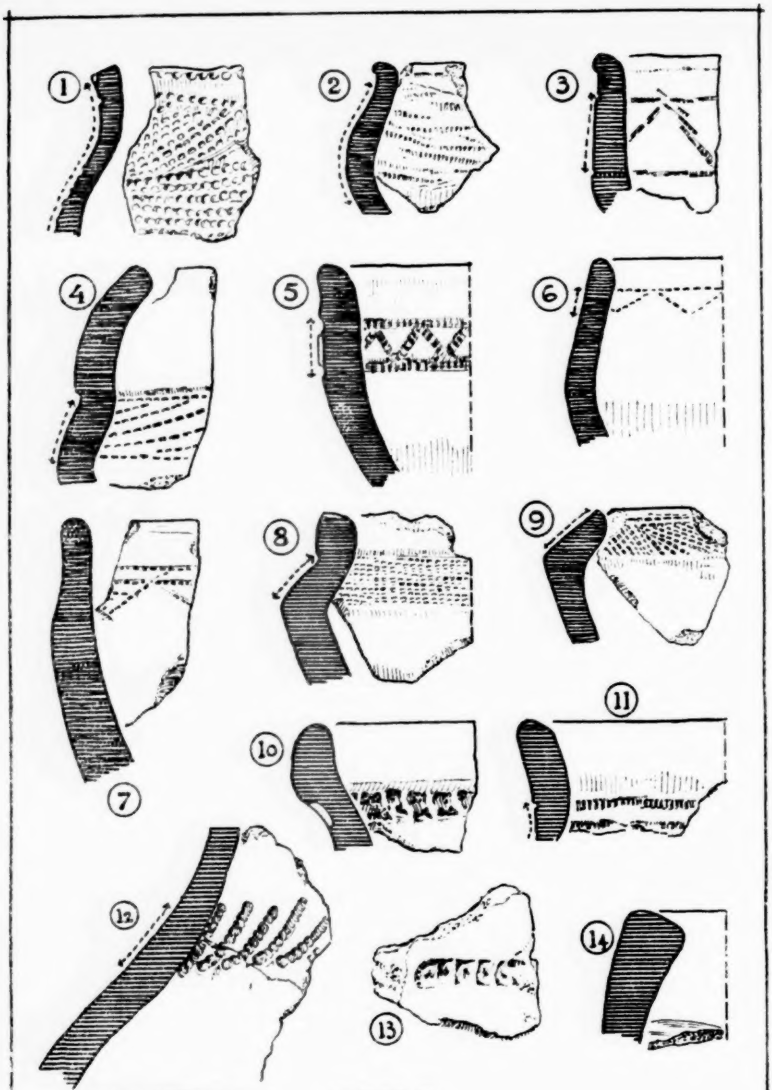

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FIG. 7.

(1) Probably a fragment of a bowl, about 12 inches in diameter. In a brown clay with a brindled surface matt externally and smooth internally. The rim was cut off square with an external bevel. The outer edge was notched, the neck was concave. The decoration consisted of two bands of comb marks, in the upper the impressions were diagonal, in the lower they were horizontal. Area II, Section M2, 6 inches to 1 foot.

(2) A fragment of a shallow bowl, about 12 inches in diameter. In a gritty grey clay with a light brown surface. The rim was rounded and finished with a small roll. Below it the surface was covered with impressions which may have been made with a bangle of coiled wire, and which were probably arranged in pendant triangles or loops. Area I, Section C2, 3 to 6 inches.

(3) A fragment of a shallow bowl, about 12 inches in diameter. In a grey ware with a brindled buff surface. The rim was rounded and finished with a small roll. Below it there was a band of triangles roughly made with a fine comb. From the Gatti collection.

(4) A fragment of a shallow carinated bowl about 12 inches in diameter. In a grey clay with a brindled grey matt surface externally. The rim was rounded. The rim band was convex and below it there was a neck band of diagonal comb marks. The upper part of the bowl, consisting of rim band and neck, had a conical section and joined the body with a carination. Area I, Section C1, 6 inches to 1 foot.

(5) A fragment of a deep bowl, about 10 inches over the rim. In a grey clay with a brown surface, matt externally. The rim was rounded, and below it there was a bold chevron band of comb marks. Area I, Section A2, 3 to 6 inches.

(6) A fragment of a deep shouldered bowl about 6 inches over the rim. In a grey clay with a light-buff brindled surface. The rim was rounded, and below it there was a neat line of pendant triangles. The upper part of the bowl was slightly conical. From Gatti collection.

(7) A fragment of a deep bowl, about 12 inches in diameter. In a grey clay with a brown surface, matt externally. The rim was rounded, and the neck slightly concave and decorated with a line of pendant triangles, formed with fine comb marks. Gatti collection.

(8) A fragment of a deep carinated bowl, about 11 inches in diameter. In a grey clay with a brown matt surface. The rim is missing, the rim band was convex, the neck was slightly convex and splayed outwards, joining the body with a sharp carination. It was decorated with a mass of fine comb marks. Gatti collection.

(9) A fragment of a deep carinated bowl, about 7 inches in diameter. In a grey clay with a brown matt surface. The rim was rounded internally. The neck was splayed and joined the body with a sharp carination. The neck was decorated with a band of comb marks. Gatti collection.

(10) A fragment of a pot about 8 inches over the rim. In a brown clay with a brown surface. The rim was rounded and everted with a bold convex rim band. Below it there was a band of deep roughly made impressions. Area II, Section C3, 6 inches to 1 foot.

(11) A fragment of a pot, about 7 inches over the rim in a grey clay with a brown surface, matt externally. The rim was rounded and everted with a convex rim band, below which there were at least two lines of comb marks. Area II, Section M1, 0 to 3 inches.

(12) A fragment of a large pot. In a coarse grey clay with a brown surface matt externally. The neck band consisted of inclined lines of bold comb marks. Area I, Section C1, 3 to 6 inches.

(13) A fragment of a coarse grey clay with a brown surface on which a line of horseshoe impressions had been made. Area I, Section B2, 6 inches to 1 foot.

(14) A fragment probably of a spherical pot. In a coarse grey clay with a matt buff surface. The rim had been thickened, flattened, and splayed inwards with rounded edges. Externally there appears to have been a band of oblique incisions. Area II, Section A3, 6 inches to 1 foot.

(15) Large fragments of a pot with a concave neck. In coarse buff clay with a blackened surface. The rim was cut square and bevelled outwards. The shoulder had a roughly made line of oblique comb marks. Area II, Section A2, 0 to 3 inches.

(16) A fragment of a similar pot to the last. The neck was decorated with roughly incised diagonal cross-hatching. Gatti collection.

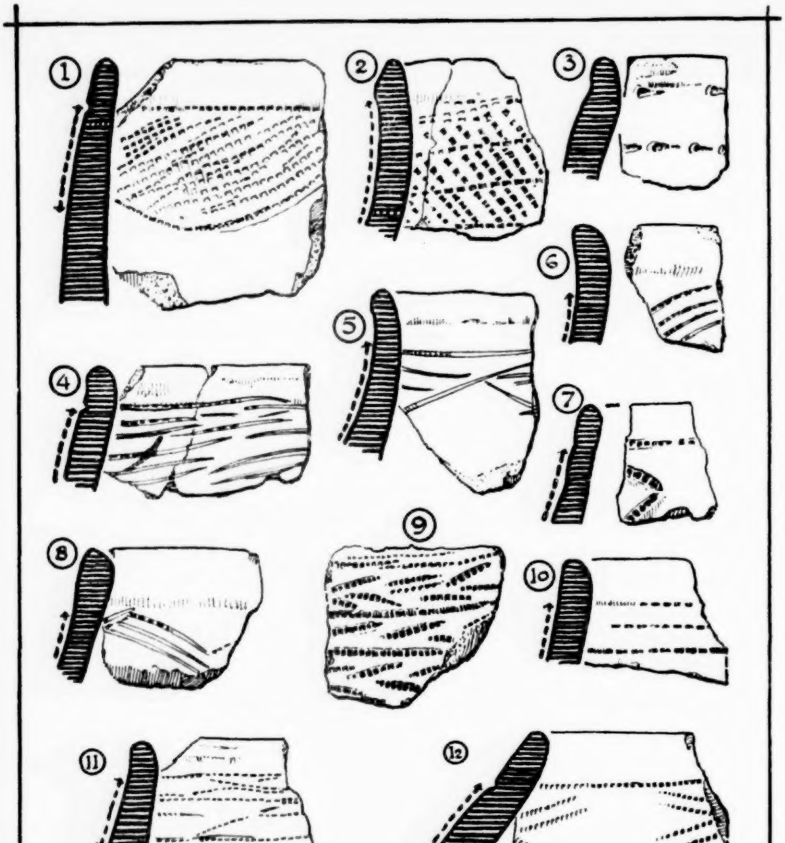
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FIG. 8.

(1) A fragment of a beaker bowl, about 10 inches over the rim. In a coarse grey clay brown internally, with a black matt surface externally. The rim was rounded with a convex rim band, below this there were long loops filled in with oblique comb marks. Area I surface.

(2) A fragment of a shouldered pot, 4½ inches over the rim. In a grey clay with a buff surface. The rim was rounded and splayed down to the neck, which was slightly concave and had three bands of oblique comb marks. Area I, Section C2, 0 to 3 inches.

(3) A fragment of a large pot. In a grey clay with a brown matt surface. The rim was rounded with a slightly convex rim band; below this there were three lines of wedge-shaped impressions. Gatti collection.

(4) A fragment of a shouldered pot, 5½ inches over the rim. In a grey clay with a brindled buff surface. The rim was rounded with a small roll. Below this there was a wide band of incisions which had been made with a fine comb. Area I, Section B1, 6 inches to 1 foot.

(5) A fragment of a shouldered pot, 7 inches over the rim. In a grey clay with a brown surface. The rim was rounded and slightly everted with an external burr; below it there was a band of freely incised triangles. Area I, Section A2, 3 to 6 inches.

(6) A fragment of a shouldered pot. In a grey clay with a buff surface. The rim was rounded and thickened with a slight ridge externally; below there is a line of oblique comb marks. Area I, Section B1, 3 to 6 inches.

(7) A fragment of a shouldered pot or a pot with a tapered neck. In a black clay with a buff surface that had been blackened. The rim was rounded and thickened externally; below this the rim had probably been covered with zigzag comb marks arranged vertically. Area II, Section B5, 3 to 6 inches.

(8) A fragment of a pot similar to (6), but it was 10 inches over the rim and decorated with roughly incised chevrons. Area I, Section B4, 3 to 6 inches.

(9) A fragment of a pot decorated with bands of oblique comb marks. Gatti collection.

(10) A fragment of a deep-bowl, 7 inches over the rim. In a grey clay with a brick-red surface. The rim was rounded, and below it there were three rows of comb marks. Area I, Section B4, 3 to 6 inches.

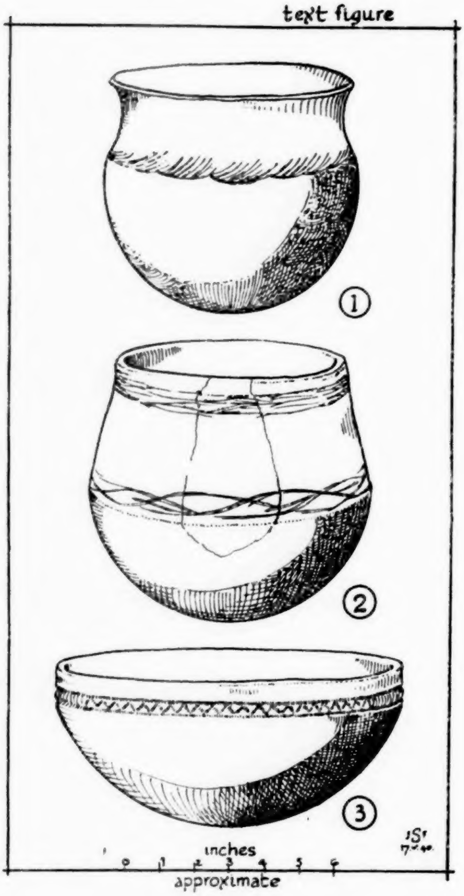
(11) A fragment of a cone-necked pot, about 6½ inches over the rim and 8 inches in diameter. In a grey clay with a brindled brown surface. The rim was rounded. The conical neck joined the body with a distinct carination. Below the rim and above the carination there were bands of rough incisions that had been made with a fine comb. Area II, Section C3, 6 inches to 1 foot.

(12) A fragment of a cone-necked pot, about 7 inches over the rim. In a grey clay with a brown surface matt externally. The rim was rounded and the rim band slightly convex. The neck had double zigzags of comb marks arranged vertically. Area II.

(13) A fragment of a cone-necked pot, about 6 inches over the rim. In a grey clay with a reddish buff surface. The rim was tapered, rounded, and slightly everted, and the neck was decorated with zigzags of comb marks arranged vertically. Gatti collection.

(14) Probably a fragment of a cone-necked pot, about 9 inches over the rim. In a greenish grey clay with a reddish surface. The rim was rounded and had a slightly convex rim band. Area I, Section A2, 6 inches to 1 foot.

(15) Probably a fragment of a cone-necked pot, about 8 inches over the rim. In a grey clay with a buff surface. The rim was brought to a ridge with a convex rim band. The neck was covered with fine comb marks. Gatti collection.



TEXT-FIG. 9.

(1) Reconstruction of No. 1, 15.
(2) Reconstruction of No. 2, 11.
(3) Reconstruction of No. 1, 5.

(*c*) The use of the stamp or comb. The greater number of the pots were decorated in this way. The following different types of impression have been noted:—

1. The use of a comb producing large square impressions.
2. Fine neat impressions (8, 12).
3. Fine incised impressions, which may have been made with the edge of a shell.

(*d*) Impressed cord—two sherds presumably from the same pot are illustrated by Wells. No sherds decorated in this way were found during our own excavations, so that this particular technique must be considered rare at Mumbwa.

(*e*) Impressions of a coiled wire bangle (7, 2).

The use of the comb or stamp made possible a variety of motifs. Triangles both plain and hatched, chevrons, zigzags, single lines, false relief, and other more elaborate designs are found, as can be seen from the figures. We must particularly draw attention to the distinctive zigzag motif with which the upper part of many of the carinated cone-necked pots is decorated (8, 12 and 13). It is probable that this is a stylised version of the effect produced by pressing first one and then the other end of the comb against the pot wall as it was worked over the surface of the vessel.

Form.—The following types are found:—

(*a*) Shallow bowls, some of which were carinated and shouldered.
(*b*) Deep bowls as last.
(*c*) Carinated cone-necked pots.
(*d*) Shouldered pots.
(*e*) Pots with concave necks.

The characteristic type of the Mumbwa pottery tradition is undoubtedly the carinated cone-necked pot (9, 2), for more sherds can be attributed to it than to any of the others. Unfortunately the only sherd large enough to justify a reconstruction belonged to a poorly finished pot. Other pieces, although less complete, suggest that very generally both the taper of the neck and the carination were more pronounced than in the example illustrated.

The meaning and origin of the carinated contour as found in South African pottery has been dealt with at length by Gardner, Wells, and Schofield in their work on the Gokomere material (5). Our pottery tends to support their conclusions that carination was originally a structural feature which tended to be used in a purely decorative manner. Further, we believe that these carinated cone-necked pots represent a primitive type from which the vertically sided beaker bowls, the basins, the spherical pots, and the shouldered pots may all have been developed.

The primitive nature of this type is also indicated by the carinated bowls (7, 4, 8, and 9) which may represent extreme modifications of the original type.

There was no evidence to point to the use of lugs, handles, or perforations, and, as far as it was possible to judge, every pot was round based. There was also no evidence of the presence of flat based or pedestaled pots.

Classification.

We believe that this pottery may be classified as belonging to three categories—

(*a*) One which includes the bulk of the material from the site, of which the carinated cone-necked pot is the characteristic type.

(*b*) Including a few vessels, mostly surface finds, also in a thin buff ware, with a poorly finished blackened surface. Several small undecorated bowl fragments appear to belong to this category, but the best preserved example is the concave-necked pot (9, 1). This ware may be connected with category (*a*), because the fragment 8, 7, which has some of its characteristics, probably belonged to a cone-necked pot.

(*c*) Including a few vessels of thin buff ware, with conspicuously flattened rims, which were sometimes notched. All examples appear to have been parts of shallow bowls (7, 1). This may have been an imported ware.

Affinities.

Gokomere.—The most obvious affinities of the Mumbwa pottery lie with the wares which Caton-Thompson called Class A at Zimbabwe and Gokomere, and which Schofield has suggested should be included under the symbol of R.1 (6). Such pieces as the carinated bowl (7, 4), the deep bowl (7, 5), are clearly connected with some of the more elaborate types from Gokomere; while the extensive use of stamped decoration and convex rim bands would indicate that the relationship was very close indeed.

On the other hand, these resemblances must not lead us into too close an identification of traditions which, although they have many points in common, have also a number of equally striking divergences.

The carinated cone-necked pots do not occur at Gokomere, and apparently they have not been recorded from Southern Rhodesia, where the characteristic vertical zigzag of comb marks is also unknown.

Spherical pots, which are occasionally found at Gokomere, have not been recorded at Mumbwa, where the deep, vertically sided bowls are unknown and the concave-necked pots are rare, although both types are common at Gokomere.

On the Southern sites the rim bands are very frequently decorated with oblique lines of comb marks. This is not the case at Mumbwa, where all the rim bands are plain. At Gokomere the only plain rim bands were those of the bowls, which had often been made by trimming off the surplus clay from the lower edge of the band, formed by tapering out the lip and then folding it over the outside of the bowl. This technique has not been found at Mumbwa.

Also the carinated profile, which is very common indeed at Mumbwa, was only found on the more highly finished bowls at Gokomere, where it also survived in the vestigial form of a line of impressions round the shoulder of the pot.

Bambata.—Two examples of our category (*c*) were found at Bambata in the course of excavations recently undertaken by the Rhodesian Museum under the direction of Mr. Neville Jones. It is probable that at this site also our category (*c*) was an imported ware.

Mapungubwe.—Several of the bowl sections (*e.g.* 7, 8 and 9) are identical with pieces from Mapungubwe, where, however, the decoration had all been incised on the wet clay.

Parma.—Rim sections and decoration, such as illustrated at 7, 11, are very similar to some of the earlier pottery from this site.

Modern Native Pottery.—The modern pottery which most resembles that from Mumbwa is to be found among the Soli living in the hill country of the Lusaka district, where the stamp decoration is most commonly employed.

Generally.—Wells in his description was relying on a few sherds only and had not a fully representative collection to work on. It was this fact, no doubt, that made him cautious in suggesting any intimate connection between the Mumbwa material and the Zimbabwe Class A pottery, and so with Schofield's R.1 pottery tradition of Southern Rhodesia. In our opinion, however, all evidence points to a strong generalised resemblance, which, although it does not amount to identity between the pottery from these places, does indicate that both had a common origin in the not too distant past.

We hope to describe in a later paper the main pottery traditions of Northern Rhodesia, so that it suffices to say here that there is a very close agreement with Schofield's classification south of the Zambesi, and we consider that his categories can be readily applied to at least the southern half of this territory.

Iron Objects.—All the iron objects found were much corroded, making cleaning a matter of difficulty. The following objects were recovered:—

Area I.—(1) The upper part of a tanged blade. Length 87 mm.; greatest width, at broken end, 12 mm. At the butt this object has been bent over upon itself, forming a hook. The blade tapers in thickness from the butt downwards. Probably the hafted end of a broken knife-blade.

(2) A broken fragment, 35 mm. long, with a round section of 4 mm. diameter.

(3) A hollow, cylindrical object, 22 mm. long, with a diameter of 10 mm.; thickness 1–1½ mm. This had been made by bending round a single sheet of iron.

(4) A small U-shaped object, possibly an ear ornament, 14 mm. long and 11 mm. greatest width.

(5) The broken working end of a flat triangular-shaped piece of iron, 28 mm. long and 22 mm. greatest width. The base appears to have been sharpened, and the object may perhaps be the remains of a razor.

Area II.—(1) A small broken triangular piece of iron, 23 mm. long and 12 mm. greatest width.

(2) Two finger-rings made of rolled iron with round cross-section, formed from a single piece of metal bent so that the two ends overlap slightly.

In addition should be mentioned the remains of three arrow-heads found by the Italian Scientific Expedition in this cave (7). These are barbed and tanged; one shows a spirally twisted tang, while the others are round in section. The head of one shows the longitudinal contraflexion found on many of the arrow-heads from this territory. The spirally twisted tang can be paralleled among the Lunda and allied tribes in the north-west. One arrow-head of this type was found by Miss Caton-Thompson at Chiwona (8).

Miscellaneous.—A few pieces of bone showing evidence of cutting with metal tools were found; one hollow cylindrical fragment had been cut and shaped at one end. A thin, round piece of worked bone was also found.

With regard to bone and shell ornaments, the writers of the Italian Scientific Expedition's report state on p. 388, concerning the most superficial stratum: "There was a greater number of bone and shell ornaments at this level"; while on p. 408 they say: "A considerable assortment of ornaments in bone and shell . . . were forthcoming, mainly from the pure stone culture region overlying the ash stratum." Fig. 24 of their report illustrates a number of ornaments, among them the mussel shell, presumably from the Iron Age level. In this connection it is of interest to note that the Ila of the Kafue Flats still attach this shell, identically pierced, to belts worn by girls dancing at the initiation ceremonies.

There was also found one fragment of burnt clay which may have formed part of a cast. It shows a smoothed, widely grooved depression on one side.

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2. THE NORTHERN RHODESIAN WILTON.

Terminology.—It is necessary to state here the reasons why this particular name has been applied to this industry. Because the industry from Mumbwa undoubtedly belongs to the Wilton ensemble but has no exact parallels in Southern Rhodesia or the Union of South Africa, and because of our lack of knowledge of any similar industry to the immediate north, it has been necessary to add the adjective "Northern" in order to differentiate this industry from that found in Southern Rhodesia. Almost exact parallels, however, are found at a number of different sites on the northern side of the Zambesi Valley and in the Lusaka, Petauke, and Lundazi districts, and for this reason it has been given cultural standing.

The adjective "Lower" first suggested itself, but although the assemblage is what one might have expected as the forerunner of the Southern Rhodesian Wilton it has not as yet been found in a stratigraphical position below this. However, on a typological basis and in view of the earlier date assignable to the deposit containing the Northern Rhodesian Wilton in the Zambesi Valley, I would suggest it to be the earlier.

Material.—Ninety-eight per cent. of the implements recovered were made from quartz—this was of four kinds.

(i) Pure crystalline quartz—only a few implements made from this recovered. In passing it may be noted that crystals were in demand as fabricators of lames écaillées type.

(ii) A semi-crystalline, and

(iii) A dull, opaque kind from which the greater number of implements are made.

(iv) A milky, more homogeneous kind was more rarely used.

In addition, chalcedony, dolerite, hornstone, ferruginous quartzite, and ironstone were also used, but implements in these materials are rare.

Quartz outcrops are a common feature of the immediate vicinity, and ironstone and quartzite could also be obtained locally, but the other materials must have been transported from some distance as they do not, as far as I know, occur in the district.

Preservation.—With the exception of certain examples from Area I all implements recovered were in "mint" condition, and for the most part unpatinated. Only the chalcedony and hornstone show a slight surface patina. The greater part of Area I, however, was outside the cave roof, and therefore the implements were subject to a greater degree of weathering than those from Area II. A number of these tools therefore show a glossy patina and the edges have often been worn smooth.

Stones showing crackle through contact with fire were conspicuous by their absence.

Description of Industry.

The following table shows the general divisions and total number of implements found in each area:—

Table of Tool Types of Northern Rhodesian Wilton.

Area.	Large Backed Blades.	Small Backed Blades.	Truncated Blades.	Crescents.	Concave-ended Blades.	Notched Blades.	Trapeziums.	Atypical Blades.	Scrapers.	Awls.	Kasouga Flakes.	Burins.	Detaching Fabricators.	Lames écaillées.	Bored Stones.†	Polished Axes.†	Miscellaneous.	Total Implements.	Factory Debris.
M1	22	180	30	54	21	8	9	28	93	7	5	70	10	19	..	1 fragment	15	567	3310
M2	19	151	54	39	5	3	9	7	76	2	2	49	4 ? *	36	5	4	17	482	4965

* A number of ill-formed pieces which I believe were used as fabricators of this kind have not been included because it is not certain if such was their real nature.

† The bored stones and three of the polished axes were found by the Italian Expedition in this cave in the Wilton stratum and have been included for sake of completeness.

It can be seen that Area I yielded the greater quantity of microliths and scrapers and also the least number of waste flakes and other factory debris. As it was not practicable to preserve every piece of waste material, only those that helped to demonstrate the procedure and technique of production were retained. It is estimated that only one in every ten, if as many, were preserved from Area I and one in five from Area II. A rough estimate of the number of waste flakes at each site has been obtained by multiplying the numbers retained by ten and five respectively. In spite of the fact that this estimate errs on the conservative side it shows that a greater assemblage of factory debris was found in Area II. Whereas the implements comprised 14 per cent. of the total material from Area I, they formed only 8 per cent. of that from Area II. It would seem, therefore, that Area II was part of a workshop floor, a fact that is substantiated by the greater

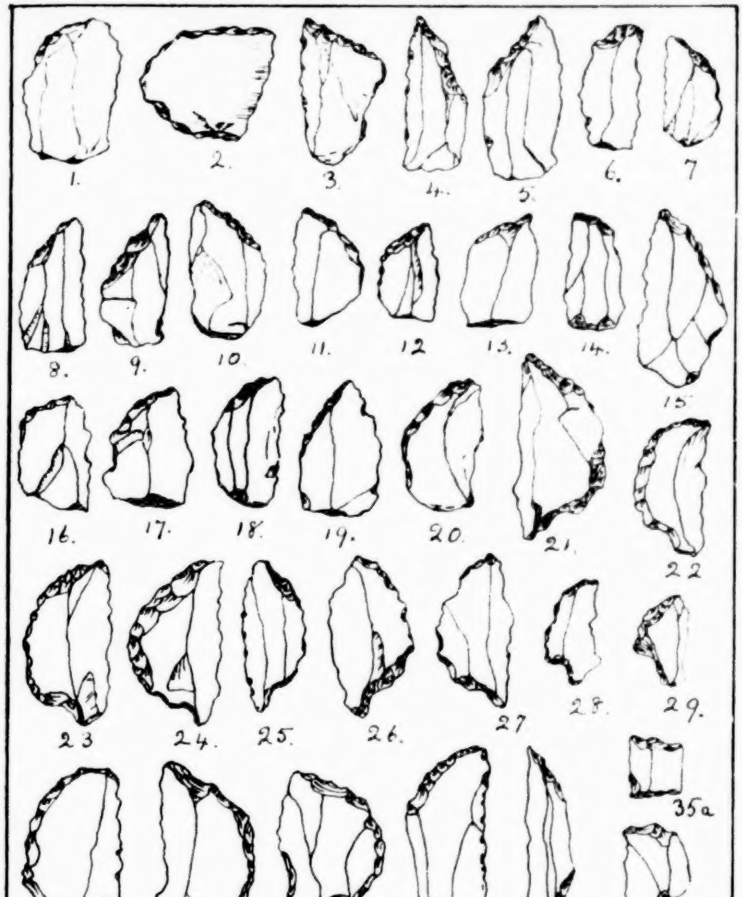

FIG. 10.—Truncated blades (Nos. 1–20), blades with concave backing at one end (Nos. 21–32), trapeziums and derivatives (Nos. 33–42).

Area I.—2, 4, 6, 7, 11, 12, 15, 19, 22, 24, 25, 28–32, 33, 37–39, 41.

Area II.—1, 3, 5, 8–10, 13, 14, 16–18, 20, 21, 23, 26, 27, 34, 35, 36, 40, 42.

All made from milky quartz except 10 and 18 chalcedony, 23 blue quartz.

(Scale $\frac{7}{8}$.)

number of fabricators recovered here. Points of interest are the comparatively small proportion of implements to waste products, and, secondly, the homogeneity of the industry as shown from an examination of the types found, no type being lacking from either site.*

(i) *Large Backed Blades* (fig. 12, Nos. 1–10).—These comprise only 3·8 per cent. of the total number of implements and are not very common; they were used presumably in the same manner as the larger Capsian and Kenya Aurignacian backed blades.

(ii) *Microliths.*—(a) *Truncated Blades* (fig. 10, Nos. 1–20).—Truncated either obliquely or straight, the resulting edge being either straight, convex, or concave. The majority retain the bulb and platform at the butt.

(b) *Small Backed Blades* (fig. 12, Nos. 16–38, and fig. 13).—Forming 41 per cent. these are by far the commonest tools found. Both Chatellperron (fig. 13, Nos. 11–63) and Gravette forms (fig. 13, Nos. 1–10) with their derivatives are present, but the former are by far the commoner.

(c) *Crescents* (fig. 11, Nos. 1–33).—Forming the next largest group of microliths they are for the most part fairly crude when compared with the Southern Rhodesian Wilton implements of this type. These and the small backed blades form somewhat ill-defined groups, often merging the one with the other. In distinguishing between the two, however, I have designated as crescents those implements that are segmental in outline and have been trimmed to a point at each end.

(d) *Backed Blades showing a Concave Notch* at one end of the backed surface (fig. 10, Nos. 21–32).—This small but interesting group is of importance, as the type, although apparently not very common, has a fairly wide distribution, being found on early Wilton sites in Southern Rhodesia and also in the Zambesi Valley, where the notched end develops into something approaching a shoulder.

(e) *Notched Backed Blades* (fig. 11, Nos. 34–41).—A few blades showing notches on the cutting edge have been found.

(f) *Trapeziums and Derivatives* (fig. 10, Nos. 33–42).—A small group, among which must be mentioned two examples of the "petit tranchet." Several other microliths (*i.e.* fig. 11, No. 32) could have been used in a similar manner however. One point of interest in connection with the transverse arrow-head is its use in hunting game by the Lunda-Luba tribes of North-Western Rhodesia. These blunt-ended arrow-heads, made of course of iron, are used for wounding a buck, thus leaving a clear blood trail so that the animal can be more easily followed up and killed.

(iii) *Atypical Blades.*—Fig. 11, Nos. 46–51, show examples.

(iv) *Scrapers.*—This group forms only 16 per cent. of the total, and com-

* It should be noted that the Italian Expedition records no bored stones from Area I.

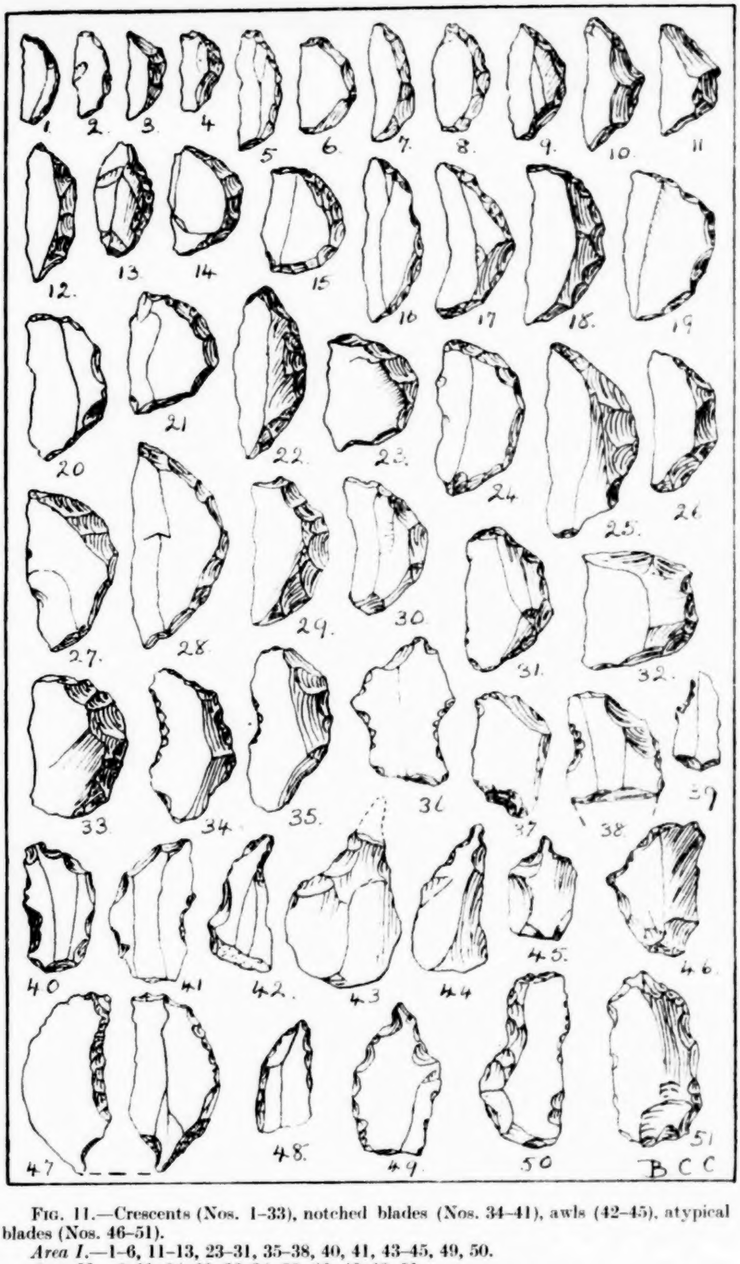

FIG. 11.—Crescents (Nos. 1–33), notched blades (Nos. 34–41), awls (42–45), atypical blades (Nos. 46–51).

Area I.—1–6, 11–13, 23–31, 35–38, 40, 41, 43–45, 49, 50.

Area II.—6–11, 14–22, 32–34, 39, 42, 46–48, 51.

All made of milky quartz except 13, 14 crystalline quartz, 33 chalcedony, 46 hornstone. (Scale $\frac{7}{8}$.)

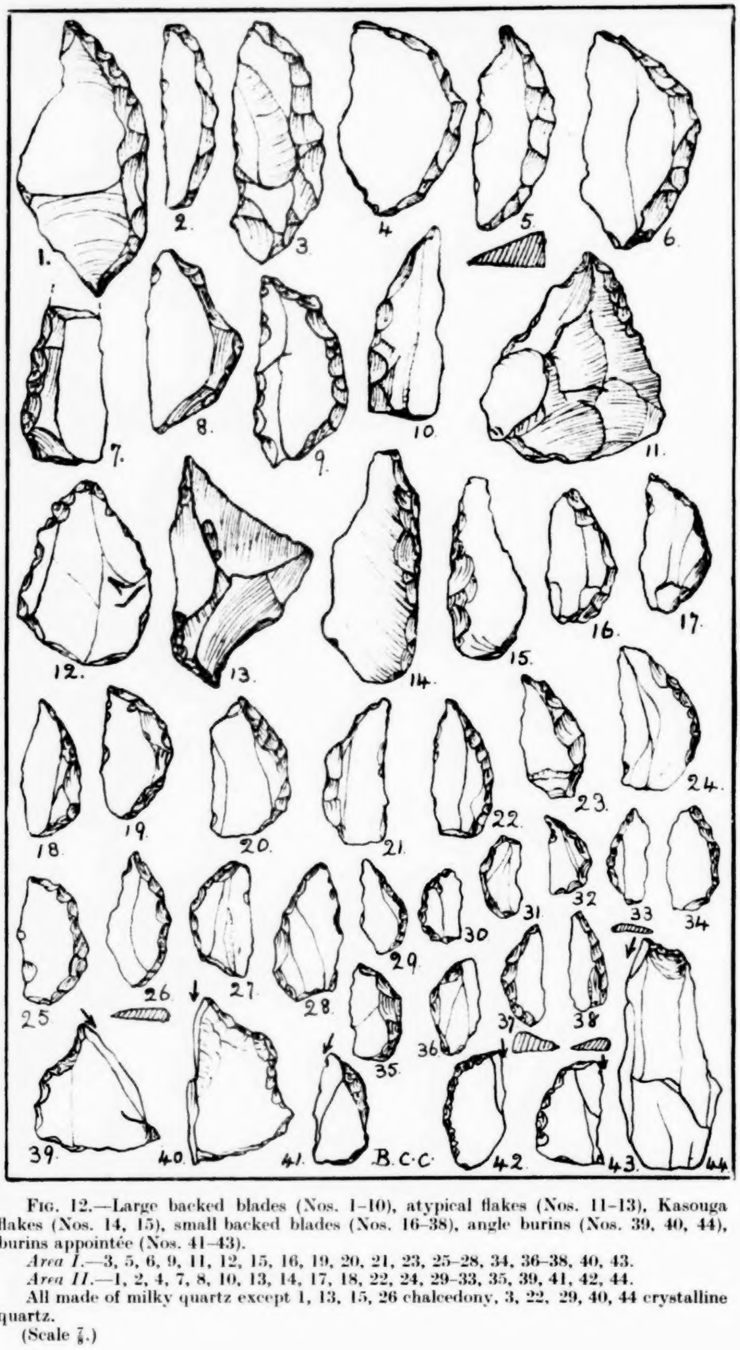

FIG. 12.—Large backed blades (Nos. 1–10), atypical flakes (Nos. 11–13), Kasouga flakes (Nos. 14, 15), small backed blades (Nos. 16–38), angle burins (Nos. 39, 40, 44), burins appointée (Nos. 41–43).

Area I.—3, 5, 6, 9, 11, 12, 15, 16, 19, 20, 21, 23, 25–28, 34, 36–38, 40, 43.

Area II.—1, 2, 4, 7, 8, 10, 13, 14, 17, 18, 22, 24, 29–33, 35, 39, 41, 42, 44.

All made of milky quartz except 1, 13, 15, 26 chalcedony, 3, 22, 29, 40, 44 crystalline quartz.

(Scale $\frac{7}{8}$.)

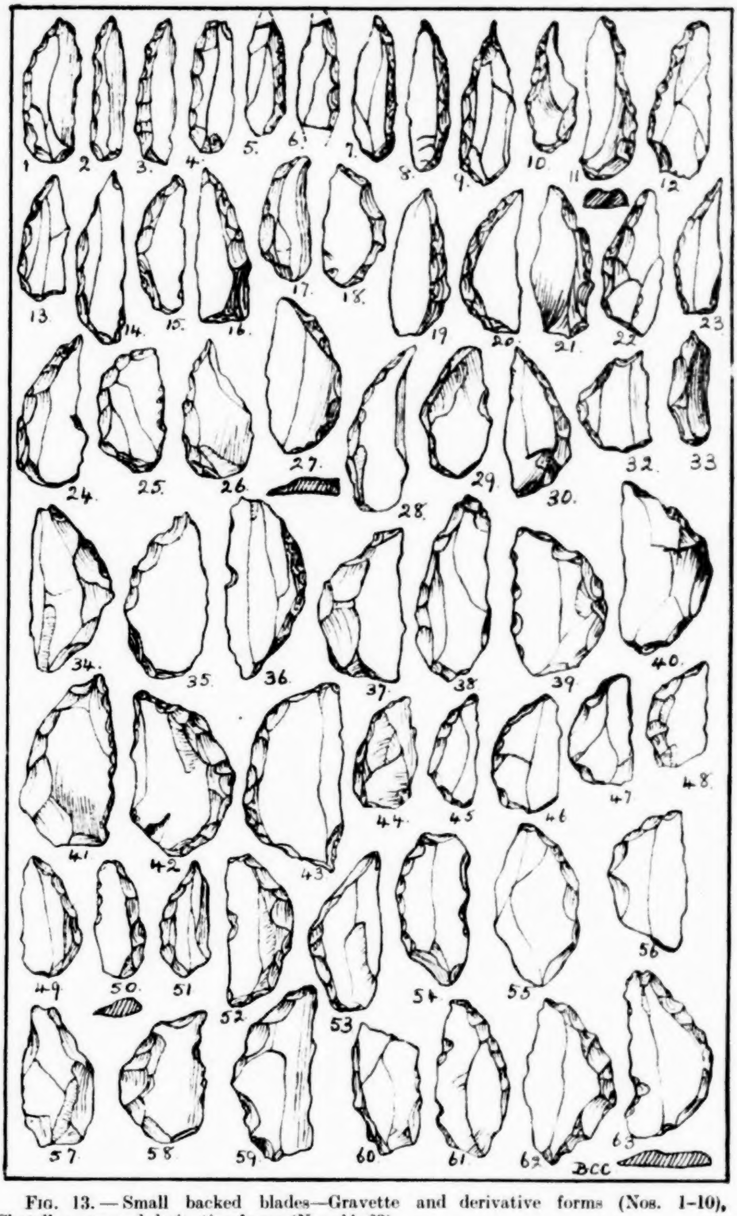

FIG. 13. — Small backed blades—Gravette and derivative forms (Nos. 1-10), Chatellperron and derivative forms (Nos. 11-63).

Area I.—4, 6, 10, 11, 14, 17, 25, 29, 32, 36-40, 47-49, 51-53, 55-58, 62.

Area II.—1-3, 5, 7-9, 12, 13, 15, 16, 18-24, 26-28, 30, 31, 33-35, 41-46, 50, 54, 59-61.

All made of milky quartz except 12, 59 chalcedony, 30, 43 crystalline quartz.

(Scale $\frac{7}{8}$.)

prises: Thumb-nail (fig. 14, Nos. 1–5) (poorly developed and for the most part larger than those found in the south); end of blade (fig. 15, Nos. 12–14); short end and round scrapers (fig. 14, Nos. 22–25, 32, and 33); these are the commonest varieties, but hollow (fig. 14, Nos. 9 and 10), side (fig. 14, Nos. 7 and 8), and small core scrapers (fig. 14, Nos. 20 and 21) are also found. The prevailing type is the end scraper, whether on long or short blade or flake.

(v) *Awls* (fig. 11, Nos. 42–45).—A few flakes showing evidence of having been worked to a point appear to have been used for piercing—if used for boring ostrich egg-shell, however, they would readily fracture.

(vi) *Kasouga Flakes* (fig. 12, Nos. 14, 15).—Rare.

(vii) *Burins.*—Almost all are made from quartz, and it is often a matter of difficulty to determine whether a piece showing the typical burin facet was used for this purpose or was simply a miss-hit—I have often come across factory sites on which the only implements to be found are burins, ordinary or bec-de-flute, and it seems evident that not every piece showing a burin facet was an actual implement.

Undoubted burins do occur, however, at Mumbwa. Bec-de-flute (fig. 14, Nos. 15–19), single blow (fig. 14, Nos. 11–14) being the commonest, but angle burins (fig. 12, Nos. 39, 40, 44, and fig. 14, No. 6) and burins appointés (fig. 12, Nos. 41–43) also occur.

(viii) *Detaching Fabricators.*—See section headed "Technique."

(ix) *Lames Écaillées.*—See section headed "Technique."

(x) *Polished Axes* (fig. 16, No. 1).—These form a small but very interesting group and are the only large core tools to be associated with the industry. All are made from massive ironstone with the exception of one broken piece from Area I made of diorite. It was suggested to me that the complete one found by our own expedition might have been made from smelted iron. The tool was forwarded to the Director of the Geological Survey at Salisbury, who replied saying: "It has a specific gravity of 5·3, whilst haematite has a specific gravity of 4·5 to 5·3 and metallic iron of 7·3 to 7·8. It gives the characteristic brown streak of haematite. I do not think it is smelted iron, but an ironstone." His report is therefore conclusive on this point. The tools have been made from rough nodules which have then been ground and polished to obtain smooth surfaces with sharp intersections especially at the cutting edges. The butt is often left unpolished.

(xi) *Bored Stones.*—Fragments from five different bored stones and one boring tool, all made of ironstone, were found by the Italian Expedition in Cave 2. One bored stone came from the "iron arrow-head stratum," but on p. 407 of their report the authors state: "One stone-boring implement (in iron ore) was found in the furnace stratum, and portions

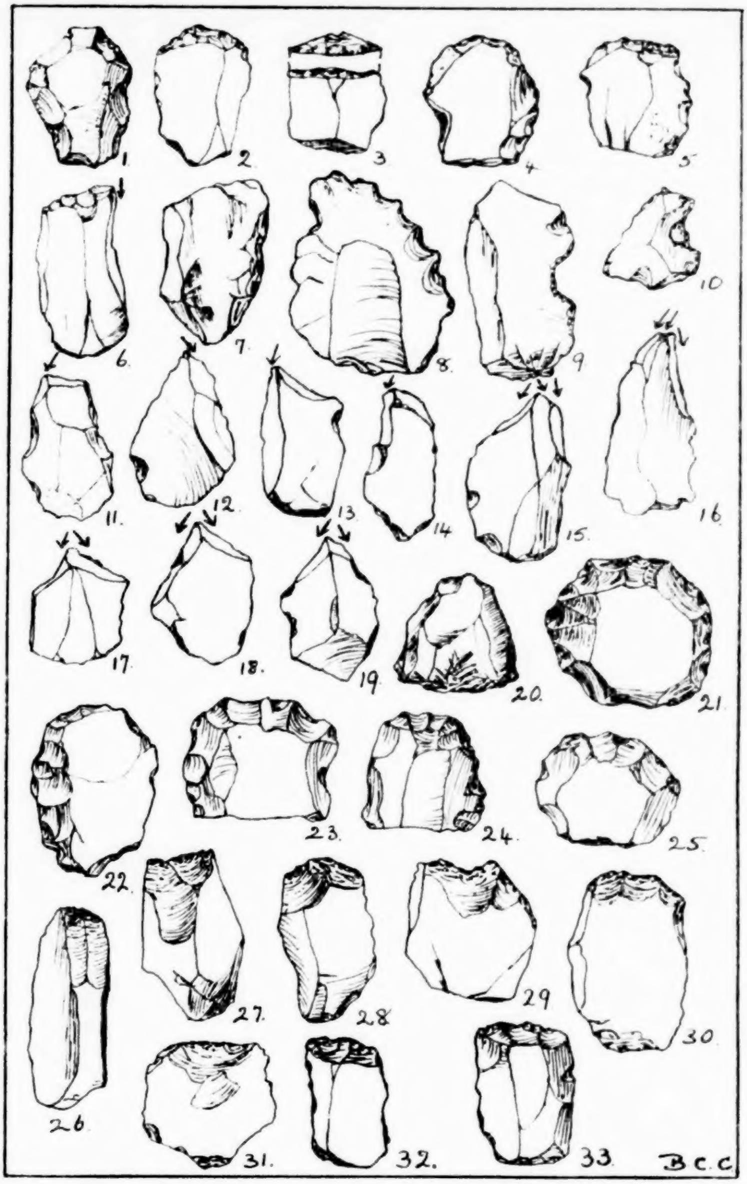

FIG. 14.—Thumb-nail scrapers (Nos. 1–5), angle burin (No. 6), side scraper (No. 7), serrated side scraper (No. 8), hollow scrapers (Nos. 9, 10), single-blow burins (Nos. 11–14), bec-de-flute burins (Nos. 15–19), core scrapers (Nos. 20, 21), short end and round scrapers (Nos. 22–25, 32, 33), lames écailleés on quartz crystals (Nos. 26, 27), lames écaillées on flakes (Nos. 28–31).

Area I.—2, 7, 8, 12–14, 17–20, 22–25, 31.

Area II.—1, 3–6, 9–11, 15, 16, 21, 26–30, 32, 33.

All made of milky quartz except 1, 7, 11 chalcedony, and 13, 26–28 crystalline quartz. (Scale $\frac{7}{8}$.)

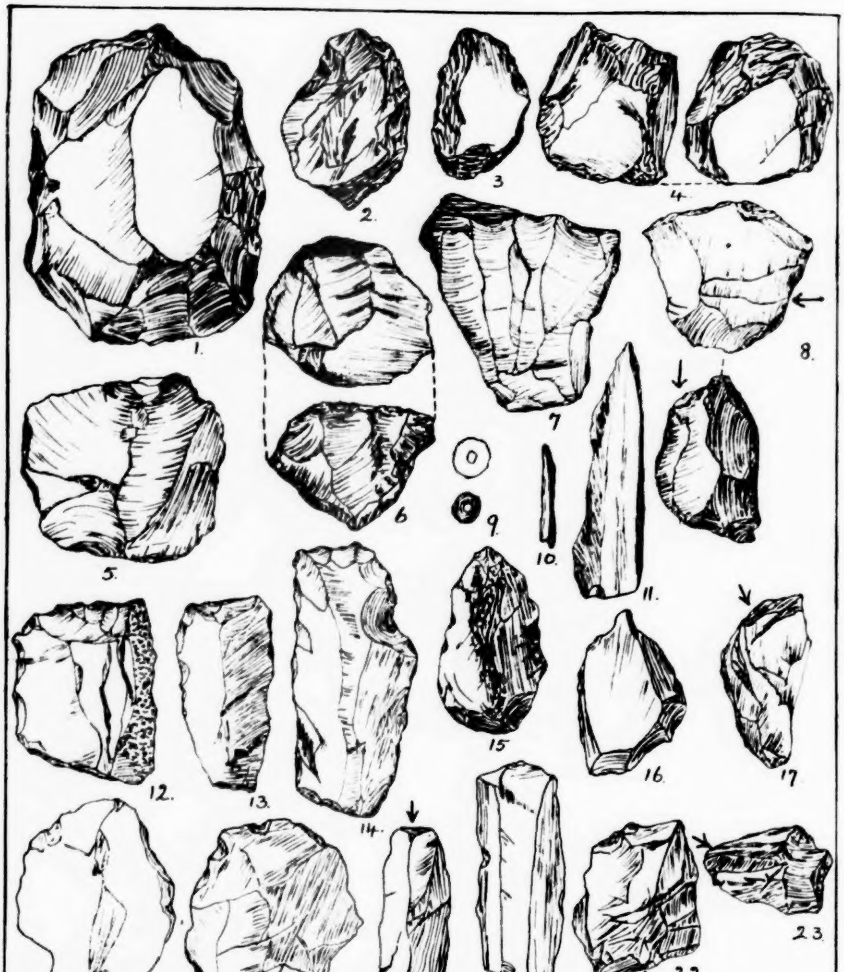

FIG. 15.—Detaching fabricators (Nos. 1–3), cores (Nos. 4–8), ostrich egg-shell and Unio shell beads (No. 9), bone tools (Nos. 10, 11), end scrapers (Nos. 12–14), redirecting flakes (Nos. 15–17, 19, 20, 22, 23), typical faceted flake (No. 18), typical blade (No. 21).

Area I.—1–3, 15, 20.

Area II.—4–8, 12–14, 16–19, 21–23.

All of milky quartz except 1 quartz zoisite rock, 23 chalcedony.

of five broken specimens of the "kwe" or Bushman digging-stone were recovered at various levels even in the furnace stratum and all executed in iron ore" (1). This statement is, I think, fairly conclusive that the

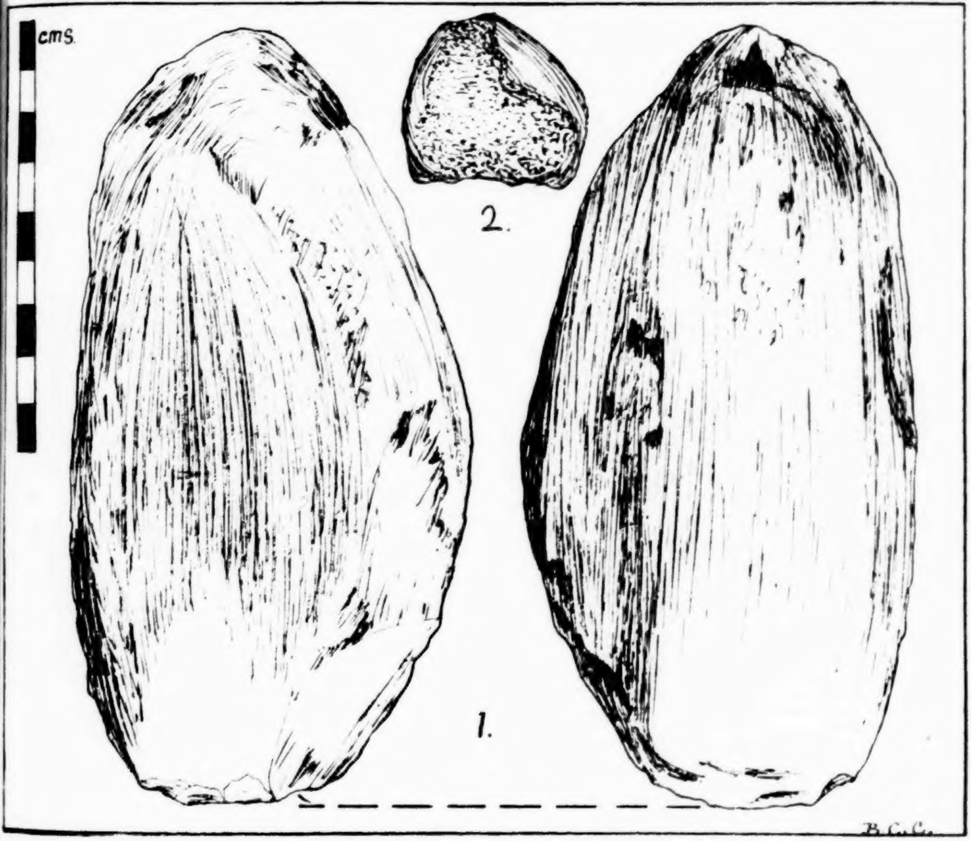

FIG. 16.—(1) Polished axe made of haematite: weight 3 lbs.; Area I. (2) Small pestle stone used subsequently as a core; Area I.

majority of the bored stones were associated with the Wilton industry and were, moreover, made on the spot.

(xii) *Miscellaneous.*—Amongst miscellaneous types may be mentioned: hammer stones, pestle stones (one used subsequently as a core (fig. 16, No. 2)), a polished pebble of quartz, a small grinding stone (?), and a few

utilised flakes (fig. 12, Nos. 11–13). The comparative absence of hammer stones is of interest. A number of small blades that appear to have undergone use on one or both edges are also found. The minute flaking to be seen in patches on them is the result of wear due to usage and not to any intentional flaking. Several uses for such tools readily suggest themselves. The edges of these and of the microliths were examined for traces of silica lustre, such as would result from cutting wild edible grasses growing in the district, but no certain traces could be found.

Technique.—It is the flake and blade element which concerns us at these sites—the core tools found comprise only a very small percentage, so that we may infer that this element was practically non-existent here. From the large assemblage of cores, trimming flakes, and fabricators it has been possible to determine the methods employed in the production of blades, and later of the microliths themselves. Fig. 15, Nos. 4–8, show examples of the different varieties of core found; Nos. 6 and 7 have a single platform and are the commonest types; the removal of a trimming flake from the platform of such a core as No. 6 would produce a pseudo-Levallois flake (fig. 15, No. 19, is an example). No. 4 is an example of a discoidal core showing three platforms, and No. 8 one showing two platforms, at opposite ends of the core. No. 5 is a tortoise core. These are not as common as might be supposed. One, two, or three flakes may have been struck from the prepared surface of cores such as these. Cores vary between two inches and half an inch in diameter, and several of the small ones appear to have been subsequently used as scrapers.

No. 21 is an example of a blade struck from a core such as No. 7, and No. 18 is a faceted flake such as was struck from core No. 5. Ninety-three per cent. of the blades and flakes recovered show an inclined unfaceted striking platform, while 7 per cent. are faceted.

When striking platforms had become blunted and no longer usable a number of different ways of rejuvenating them were devised. No. 19 is a flake struck on the same plane to remove the whole platform; No. 16 is a flake struck in a similar manner to remove half the platform; No. 22 was struck at right angles to remove one edge; No. 23 was struck obliquely to remove one edge; and No. 17 struck at right angles to remove one edge and side. A redirecting flake, such as No. 20, removed the apex and side. No. 15 is a flake showing a battered keel.

The comparative rarity of hammer stones seems to suggest that another type of implement was used for removal of flakes and blades. A number of such have been recovered, and are identical with those tools described by Professor van Riet Lowe and Rev. Neville Jones as "trimming stones." These implements vary in size between 1½–2½ inches in greatest length. They are ellipsoidal in outline and sub-segmental in section. Flakes,

often of a resolved nature, have been struck from the flat under-surface all round the core. Battering in a number of places round the periphery is commonly found. When they became too small or too badly battered they were thrown away. They were employed here as fabricators for detaching the flakes and blades for the production of microliths.

The backing on the microliths and backed blades was produced by a pressure technique, the fabricator being the lame écaillée. Dr. Leakey first showed that the lame écaillée was a fabricator when describing its use in connection with the Elmenteitan Culture in Kenya, where it is a type tool (2). It is also a type tool of the Mumbwa Wilton, two varieties being found. The one is made on flakes, and often both ends show the characteristic écaillés (fig. 14, Nos. 26, 27), the other, not so common a variety, is made on the end of a quartz crystal (fig. 14, Nos. 28–31). It is interesting to note that this is the typical form found with the Southern Rhodesian Wilton. In addition should be mentioned a number of flakes and convenient nodules that bear a few typical écaillés scars. These probably served as similar fabricators, but in the majority of cases it is impossible to tell for certain if such was their use.

The microliths themselves were made from suitable blades and never by the notch method typical of the Tardenoisian, Capsian, and Kenya Aurignacian. The true micro-burin is absent from this area.*

Backing on microliths is almost invariably directed from the flake surface, not one having been recovered where the flaking is all from the upper surface. Occasionally, however, especially on the larger blades, the backing is directed from both sides.

In connection with the probable use of the microliths as arrow barbs it is interesting to note that out of fifty-six broken halves from Area I and thirty-nine from Area II, thirty-three from the former and twenty-one from the latter were found to be the bottom halves. Only eight from Area I and the same number from Area II were the top or pointed ends—the rest were indeterminate. It would seem, therefore, that it was the top pointed end that sustained the use, which would be the case if these implements had been employed as arrow barbs. The arrow shafts containing broken barbs would be carried back to the cave for refitting.

* I have two examples from Mumbwa that may possibly be described as micro-burins, and three examples from sites in the Zambesi Valley. From the great rarity of this by-product of a specialised microlithic technique it must be inferred that this technique was not practised in Rhodesia. I have not seen any examples from Southern Rhodesia. In connection with the production of the smaller microliths it is of interest to note that, whereas many were made from blades broken transversely, others were produced from the upper part of a blade struck obliquely from one edge, usually thickened; the lower half shows an oblique burin facet. It is possible that this is a degeneration from the notch technique.

Probably each microlith could be used only once—which accounts for the number found.

Pigments.—Although no evidence of paintings was discovered on the walls or roof of the caves a number of fragments of material from which pigments could and, judging by the striae marks found upon them, undoubtedly were made, came to light in both the Wilton and the Stillbay deposits. Major Lightfoot's report on these and on other material submitted will be found in Appendix III of this report. Haematite was the material most commonly found producing a variety of shades of red and brown. For the most part the colours found in the Wilton zone are darker than those from the Stillbay, and range from chocolate through light and dark brown to red.

Skeletal Remains.—Although a very careful watch was kept no human skeletal remains other than teeth were found. This was not unexpected in Area I, where very little of the faunal evidence other than teeth had been preserved, but we had hoped for more from the second cave, where fragments of animal bones were plentiful.

The following human teeth were recovered:—

Area I:	0 inches to 3 inches . . .	2 Premolars.
		2 Canines.
	3 inches to 6 inches . . .	4 Molars.
		1 Fragment of Incisor.
		1 Premolar.
		1 Fragment of Canine.
	6 inches to 1 foot . . .	2 Premolars.
	1 foot to 1 foot 6 inches . .	1 Fragment of Molar.
Area II:	0 feet to 6 inches . . .	1 Canine.
		1 Premolar.
	1 foot 6 inches to 2 feet . .	1 Canine.

These teeth were submitted to Dr. Broom, who replied that it was not possible to determine the race to which they belonged. He says: "One tooth is a large canine (1 foot 6 inches to 2 feet, Area II), larger than Korana or most Bush canines, but occasionally a Bush canine is larger."

Our own evidence must therefore be considered indefinite, but not so that of the Italian Expedition. The remains discovered by that Expedition in Cave 2 have now been redescribed by Mr. T. R. Jones, who finds that they are principally those of the Bush and Boskop types (3).

It will be seen that the greatest depth at which skeletal remains were found was not quite 8 feet from the surface, and those nearest the cave floor were recovered at a depth of from 1 foot 6 inches to 2 feet 9 inches

only. All were found, therefore, either in the Wilton zone or in the Stillbay deposit beneath. Judging from the physical types it seems highly unlikely that men of the Bush stock were responsible for the superficial Iron Age culture with its hint of a pastoral existence, and I think we may, with every degree of certainty, assign the remains to one or both of the underlying deposits.* It was established that in the uppermost levels—that is to say in the Wilton zone—the remains were not buried but dumped with scant ceremony, which is perhaps the cause of their very fragmentary condition. Possibly these were the last Wilton inhabitants of the cave who were either killed or died from some epidemic. Beneath the Wilton zone, however, we get definite evidence of actual burial. The physical types are similar to those above except that there is a greater proportion of hybrid types.

Three graves were found by the Italian Expedition composed of rounded blocks of limestone carefully laid in position. Two of these graves were against the north wall and towards the back of the cave. The cave wall formed one side of the grave, and against this the stones were carefully piled up over the body. The ground plan was oval, and the bodies were probably buried in the foetal position.

When these facts, together with that of the actual condition of the remains themselves, are taken into account I would consider these remains to represent true burials from the Wilton zone, and not remains of the makers of the Stillbay -industry, assuming that the deposit was on an average of a uniform thickness above the burials. The deepest of these graves was not quite 5 feet below the base of the Wilton zone. Corroborative evidence for deep burial and the use of stone comes from the Naron and Namib bushmen.

Bone Implements.—The almost total absence of bone implements or fragments of implements is an outstanding point, and we are led to conclude that any extensive working in bone was quite unknown to the makers of the Northern Rhodesian Wilton. It is possible, however, that we have at Mumbwa only half the picture of those people—the cave may have been inhabited seasonally, or at any rate sporadically, and were we to excavate one of the numerous small rock-shelters to be found near the Kafue on the Great West Road we might obtain the other half of the picture. Whereas the principal form of diet at Mumbwa was mammalian, near the Kafue fish would play an increasingly important rôle, and bone or wood points, if used as barbs for fish spears, would no doubt replace to a certain extent the microlithic barbs. The only bone tools from Mumbwa

* A cone-necked pot similar in form and decoration to those from Mumbwa was recently found with a burial near Kalomo. The skeletal remains are stated to be predominantly Negro.

are rough and quite distinct from the delicate points found with the Southern Rhodesian Wilton (fig. 15, Nos. 10, 11).

Ornaments.—As well as ostrich egg-shell and mussel-shell beads (fig. 15, No. 9), the petrous bones of small animals and other pierced bones were apparently used as ornaments. In one section in Area II a small cache of ostrich egg-shell was found. This might have formed part of a shell container, but as only a few of the fragments fit together it is more probable that they were broken pieces collected for future use.

Burnt or Sun-dried Clay.—Fragments of clay of varying size were found throughout the Wilton and the Iron Age levels. That from the most superficial stratum is very much more compact than that below. At first we were of the opinion that this was material from old white-ant heaps, but after a detailed examination and comparison with existing ant heaps this appeared no longer likely, although some of the pieces may be the work of termites. It is interesting to note that we found none of these within the caves themselves, though a number of ant-hills existed in the near vicinity. Typical fragments were submitted to Major Lightfoot, who confirmed the opinion that they were burnt clay and were similar to pieces found on the sites of old native huts. Many of the fragments from Mumbwa show clearly the impression of the sticks forming the framework, presumably of some structure. Had the clay come from covered basket-work it would presumably show some impression of the technique or pattern; such is not the case however. The screen or wind-break, if such it was, made by the makers of the Wilton was a very flimsy affair, as testified by the small-sized holes in the clay, and must have been made of twigs, branches, or even grasses, plastered with a loose covering of mud. The distribution of this material throughout the Wilton zone would seem to suggest the superposition of a number of structures of this type.

During our excavation in Cave 2 in sections of Area II we found three flat limestone slabs laid end to end, and suggesting that they formed part of a sequence of which the rest was unexcavated—they all lay at the same depth from the surface and rested on and were covered by the black or upper cave earth; certainly they did not form part of a grave, and it may be that they denoted the outline of some screen—the cache of ostrich egg-shell was found within the area enclosed by them. For want of any more definite proof, however, the question of Wilton clay-covered shelters must remain conjectural.

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3. The Rhodesian Stillbay Industry.

There is nothing to distinguish this industry from the Stillbay industries in Southern Rhodesia, unless it be perhaps the presence of a number of round stone balls. The industry was not as well represented as the Wilton, so that I will do no more than recount briefly the main tool types and describe the technique.

(i) *Bifaced Points.*—These, together with the second variety, form the main types found. The commonest forms are triangular and leaf-shaped. Only five complete points were found, but quite a number of broken fragments were recovered. All are for the most part on the small side (fig. 17, Nos. 1–4).

(ii) *Unifaced Points.*—A greater number of these occur—in shape they are similar to the bifaced variety. The flake surface is unworked and the remains of the faceted striking platform can often be seen. Some of these tools are quite small (fig. 17, Nos. 5–9).

(iii) *Backed Blades.*—Five have been recovered. The backing is of a very much cruder nature than that found on the Wilton backed blades. They were evenly distributed from top to bottom of the red cave earth (fig. 17, Nos. 11–14).

(iv) *Microliths.*—Two crescents and possibly a third were found in the upper levels of the red earth (fig. 17, No. 15).

(v) *Scrapers.*—These form the commonest group of implements and are of various kinds; end (fig. 17, Nos. 21–24), side (Nos. 25, 26), hollow (No. 18), and serrated (Nos. 19, 20) forms all being present.

(vi) *Large Core Tools.*—These are comparatively rare, but their occurrence is nevertheless of interest. They are of two kinds: those flaked on both edges to produce a kind of pseudo *coup-de-poing* (fig. 17, No. 30) and those flaked on one edge only to produce a chopping tool (fig. 17, No. 32). In all probability it was, therefore, an implement approximating to the former kind that was found by Macrae in the lower levels of the red earth, and that has given rise to the suggestion of an industry of hand-axes. These tools are the only heavy axe elements in the industry.

(vii) *Round Stone Balls.*—These are fairly common, and that their shape was intentionally produced and not fortuitous can be seen at a glance. The method of production appears to have been to bang the stones on some convenient anvil and batter them to the required shape—all show the characteristic shatter marks and minute incipient cones resulting from this technique. Their presence is the one feature that distinguishes this industry from the Southern Rhodesian varieties. They are made from quartz, dolerite, and haematite, and were presumably used in connection with a bolas-like weapon, for their weight and size would preclude their

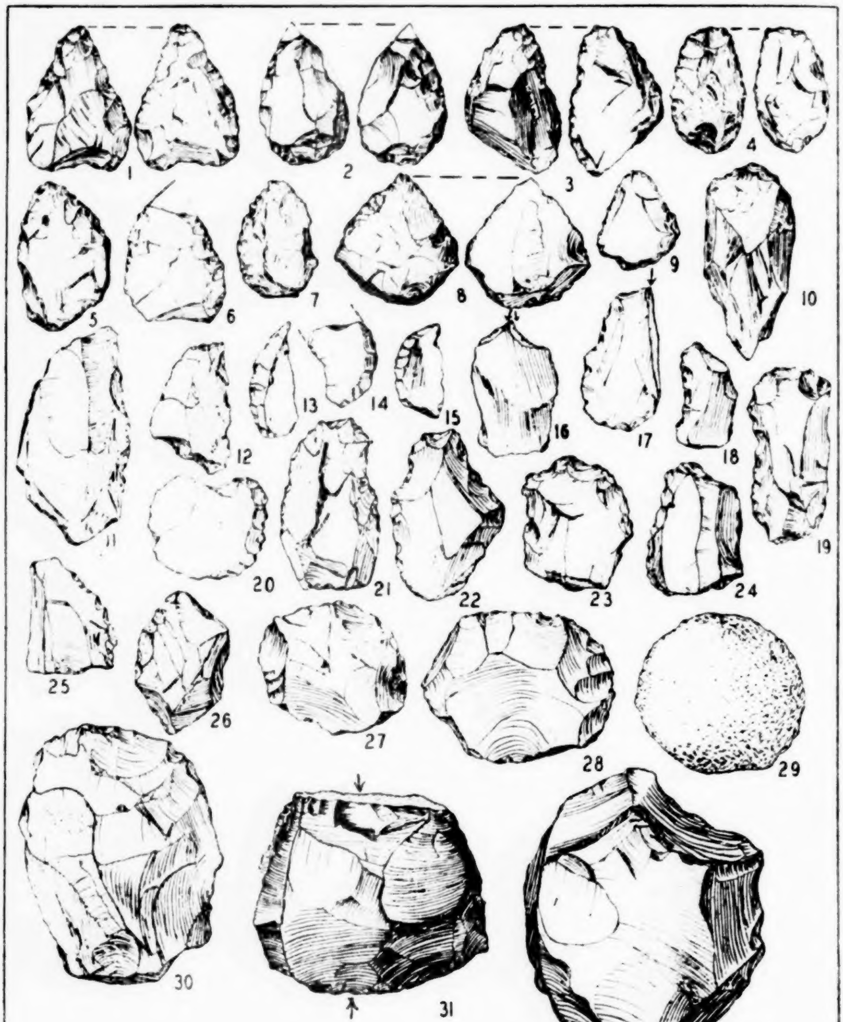

FIG. 17.—Bifaced points (Nos. 1–4), unifaced points (Nos. 5–9), lame écaillée (No. 10), backed blades (Nos. 11–14), crescent (No. 15), bec-de-flute burin (No. 16), single-blow burin (No. 17), hollow scraper (No. 18), serrated scrapers (Nos. 19, 20), end scrapers (Nos. 21–24), side scrapers (Nos. 25, 26), disc (No. 27), tortoise core (No. 28), round stone ball (No. 29), chopping tools (Nos. 30, 32), formless core with two striking platforms (No. 31).

All from the Stillbay zone in Area I.

All made of milky quartz except Nos. 2, 6, 28 of chalcedony, Nos. 25, 32 of quartz zoisite rock, Nos. 10, 13 of crystalline quartz, No. 29 of haematite, and No. 31 of hornstone.

(Scale ½.)

use as sling stones. A typical example and of average size is illustrated in fig. 17, No. 29.

(viii) *Hammer Stones.*—Several of these were recovered.

(ix) *Pestle Stone.*—One pestle stone of weathered dolerite was found at a depth of 4 feet 6 inches.

(x) *Pigments.*—A number of fragments of colouring material were recovered. A list of the colours is given in Appendix III. Besides haematite, giving a red colour, graphite schist yielding grey and limonite yielding yellow also occur.

(xi) *Discs.*—Several of these implements were found (fig. 17, No. 27).

(xii) *Burins.*—Both bec-de-flute and single blow forms are found (fig. 17, Nos. 16, 17).

Technique.—Both faceted and unfaceted flakes occur, the former variety comprising 68 per cent. of the total. The faceted flakes are of two main forms—either broad and subtriangular or long and blade-like. These were struck from different types of cores. The former from the oval or subtriangular tortoise core (fig. 17, No. 28) and the latter from a flattish long core having usually one faceted platform—the flakes being struck down one long side only. The unfaceted flakes, nearly all long and blade-like, were derived from formless cores with unfaceted platforms—one or two platforms being found on each core (fig. 17, No. 31).

It is interesting to note that the makers of the Stillbay industry utilised such materials as hornstone and ferruginous quartzite to a much greater degree than did the Wilton peoples when the use of such material was exceptional. The pressure flaking on the points seems to have been produced by using a fabricator of the lame écaillée variety; several of these were found, made on quartz crystals. This is possibly rather surprising, as a wooden or bone fabricator is what would perhaps be expected.

Affinities.—From the above it will be seen that only in the use of the round stone balls does the industry depart from the type Rhodesian Stillbay and undoubtedly intimately belongs to the same culture. The stone ball may simply be a local variation. The Mumbwa industry most resembles that from Nswatugi in that the presence of the backed blades and microliths, coupled with the smaller size of the points, seem to suggest that typologically it is a little later than the Bambata industry. Whether in point of time this is later we are unable to say.

Part IV.—The Affinities of the Northern Rhodesian Wilton Culture.

From a comparative study of the Wilton industry at Mumbwa, typical of the Northern Rhodesian Wilton Culture, and other African cultures

showing microlithic Wilton characteristics, it has been found possible to consider that the Mumbwa industry itself forms but a stage in a process of migration and local hybridisation of an original Wilton complex. It would therefore be of interest to examine briefly the points of similarity and difference between the Mumbwa industry and those other Late Stone Age industries belonging to or connected with the Wilton complex, with a view to determining the probable origins of the ancestral Wilton and also of the localised varieties of Wilton occurring in the subcontinent.

Two indications have led me to consider that the Wilton of the south is later in date than that of the north: stratigraphy and, in conjunction, typology. To deal first with stratigraphy.

Leakey has shown that the Kenya Wilton A and B belong to the East African post-pluvial wet phase, the Makalian, which is thus earlier than the date at which the Wilton appears anywhere to the south (1). Proceeding southwards we find that in the Zambesi valley we are able to distinguish on stratigraphical and typological evidence two divisions of the Northern Rhodesian Wilton. The earlier, containing a very few advanced tortoise cores, discs, and faceted flakes, as well as the usual other elements, is found in the top 2 feet of the lower terrace (possibly to be equated with the end of the Makalian wet phase in East Africa) and elsewhere covered by a deposit of from 1 to 3 feet of wind-blown sand. It belongs therefore to the very end of the wet period previous to the present period of valley cutting. The later division has so far been found only on the surface, and contains, in addition to the usual tool types, small shouldered points. That phase of the Wilton represented at Mumbwa belongs to a period of increased rainfall probably to be equated with the final wet phase.

Now, in Southern Rhodesia at the Bambata and Chelmer spruits Armstrong and Soloman found that the Wilton undoubtedly belongs to the present climatic period of river cutting, and that the implements of this culture rest always on the surface (2).

In the Union the greater part of the Wilton is presumably later still. Van Riet Lowe has shown that the Vaal River Wilton, which he says resembles most nearly the Southern Rhodesian Wilton, belongs to the present period of river cutting (equated with the Nakuran wet phase of East Africa) (3). Hewitt has found that on the south coast a Wilton resembling the Rhodesian Wilton of Gokomere is earlier than and underlies the typical Cape Wilton (4). The Developed Wilton, with shell crescents from the Oakhurst shelter, Goodwin has shown is later still (5), and we know for an historical fact that the Wilton continued to a much later date in parts of the Union than it did in either of the Rhodesias.

Next, to consider the typological evidence for the later date of the Southern Wilton and to compare this with the variation found in Northern

Rhodesia. The first point to be reckoned with is how far the different varieties of implement are of purely local and how far of cultural distribution. Obviously certain types may be more abundant at one site than at another, so that the only types that have been used for comparison purposes (see Table) are those that are considered to have a wide distribution both geographically and culturally.

Of the Late Stone Age industries of Southern Rhodesia I have selected that from Sawmills first as it is presumably the earliest in date (6). Common to the two industries (of Mumbwa and Sawmills) are crescents and backed blades, almost identical in size and type at the two sites. These comprise Chattelperron and Gravette forms, blades with concave backing at one end, and developments of the trapezium. The two latter forms occur less frequently at Sawmills, where the larger backed blades are also rare. The double-backed point is found only at Sawmills, but the petit-tranchet is entirely absent. Scraper forms are also common to both industries, but they occur in much greater variety at Sawmills, especially in the case of the thumb-nail scraper, which at Mumbwa is both crude and rare. End of blade, scrapers, burins (not the Tardenoisian micro-burin), and fabricators of both kinds occur in each industry, the type of lame écaillée fabricator at Sawmills being usually made on a quartz crystal. Polished axes and bored stones do not occur at Sawmills.

Here must be mentioned two major distinctions between the two industries. The first point of difference is the entire absence of bifaced and unifaced points at Mumbwa. While this implement is not very common at Sawmills it does definitely occur there in both its forms, but even after sorting through some eight or nine thousand implements and waste products from the Wilton zone at Mumbwa we did not come across one implement or fragment of an implement that could be described as a "point."

The second distinction is that whereas only about 10 per cent. of the cores from Mumbwa were of the discoidal variety, those from Sawmills, with which I include the flat disc-like implements similar to the diminutive tortoise core (which, by the way, does not occur at Mumbwa), comprise about 70 per cent. of the cores found. In the same way faceted flakes show increase.

Now these two differences are, it is maintained, of considerable importance, as they accentuate the quite considerable "Middle Stone Age" element pertaining to the Sawmills industry, and show that, whereas this element is present, it is not nearly so strong at Mumbwa. It may be that material has played some part in the matter of the core forms, but I see no reason for supposing this to be at all decisive, as perfectly good examples of the tortoise core were found at Mumbwa with the Stillbay industry,

TABLE SHOWING THE DISTRIBUTION OF CERTAIN TOOL TYPES IN THE STILLBAY AND WILTON INDUSTRIES OF RHODESIA.

Industries.		Basic Stillbay Types—mainly Large.			Types Common to Both.		Basic Wilton Types—mainly Microlithic.				Wilton Introductions.				
		Tortoise Cores.	Levallois Flakes.	Points.	Large B. Blades.	Burins.	Blade producing Cores.	Blades.	Thumb-nail Scrapers.	Crescents.	Double B. Points.	Polished Axes.*	Bored Stones.	Bone Tools.	Egg-shell Beads.
Stillbay.	Bambata.	× × ×	× × ×	× × ×	×	× × ×	× ×	× ×	—	×	—	—	—	—	—
	Mumbwa.	× × ×	× × ×	× × ×	×	× ×	× ×	× ×	—	×	—	—	—	—	—
	Nswatugi.	× × ×	× × ×	× × ×	× ×	× ×	×	×	—	—	—	—	—	—	—
Magosian.	Sawmills.	× × ×	× × ×	×	× ×	× × ×	× ×	× ×	× ×	× × ×	×	—	—	—	—
Wilton.	Zambesi.	×	×	—	× ×	× × ×	× × ×	× × ×	× ×	× × ×	—	× ?	—	—	×
	Mumbwa.	×	×	—	× ×	× × ×	× × ×	× × ×	× ×	× × ×	—	×	×	×	×
	Bambata.	×	×	—	×	× ×	× × ×	× × ×	× × ×	× × ×	× ×	—	—	× ×	× ×
	Gokomere, N. & M.	×	×	—	—	× ×	× × ×	× × ×	× × ×	× × ×	× ×	×	×	× ×	×
	Nyazongo.	—	—	—	—	× ×	× × ×	× × ×	× × ×	× × ×	× ×	× ×	×	?	?

× = rare. × × = occurring in small numbers. × × × = common. — = absent.

* As well as those mentioned in the text, fragments of 2 polished axes were found at Kanyankunde and unpolished axes are found on sites in the Zambesi valley [illegible] and in rock shelters in the [illegible] district; all were found with the Wilton.

and agate, from which a number of these implements were made at Sawmills, is just as refractory as quartz.

Next comparing the Mumbwa industry with the true Wilton industries of Southern Rhodesia, the distinction is not so much one of tool types as of proportion and size. The Wilton is essentially a pigmy or microlithic culture with many thumb-nail scrapers, small crescentic backed blades, pigmy burins, awls, diminutive cores, etc. It can be seen at a glance that the Mumbwa industry diverges from this general description in a number of ways, and if compared with individual Wilton industries this divergence becomes even more obvious.

To deal first with the industry from Bambata (7), which is probably the earliest of the true southern Wilton industries. Here the large backed blades are absent, the concave-ended microlith is only rarely found, the double-backed point occurs. More geometric forms such as the triangle and trapeze derivatives are frequent, and the implements are on the whole smaller than those from Mumbwa. From the point of view of technique and core production there is little difference except that the flake variety of lame écaillée is absent, as it is in the industries from Nswatugi, Madilyangwa, and Gokomere. The bone industry is a new development. Burins are no different from those at Mumbwa except that they are on the whole smaller. The typical and almost the only forms of scraper found are the thumb-nail and the small round scraper. Stone mullers are present, but the polished axe, or for that matter any axe implements, are absent.*

Secondly, the typical Southern Rhodesian Wilton of Nswatugi, Madilyangwa (8), and Gokomere (9). Here is found relatively the same technique and method of production. A very few larger backed blades occur, but the majority of the implements are quite small varieties of crescents, backed blades (both of which are common), and variations of the triangle —the trapezium and its derivatives being absent. The double-backed blade is fairly common. The typical scraper form is the thumb-nail. Burins are the same in all these industries. The developed bone industry, the slate palettes, polishers, grooved stones, and stone rings cannot be paralleled at Mumbwa. The fragment of a polished celt from Nswatugi recalls, however, the Mumbwa polished axes. Gokomere has yielded two polished axe implements, and the rough granite core tools may also perhaps be included as representing the axe element. Bored stones have also been found with the Wilton in this cave. A small fragment of burnt clay with wattle marks was found with the Madilyangwa Wilton.

Thirdly, there is the probably later Nyazongo Wilton (10). Whereas the microlithic implements are no different from the typical southern

* The implement figured by Jones on p. 75 of his "Stone Age in Rhodesia" may have come from the Wilton zone.

Wilton, yet the presence of polished and flaked axes is of considerable interest. These implements can only have been made on the spot and there is no reason to dissociate them from the rest of the industry. Here also it seems as if some of the pottery, which in the main comes from the most superficial level, was contemporary with the stone industry. A fragment of a bored stone was also found in this cave.

Finally, I will do no more than mention one of the most striking differences. This is the naturalistic art tradition present in the southern industries, but, as far as is known, absent in the northern. It is interesting to note that Northern Rhodesia, which must have lain directly in the path of any southward migration, has not yet yielded any evidence of naturalistic paintings such as are associated with the Southern Rhodesian Wilton. Those few naturalistic paintings that are known to occur resemble much more the Rhodesian Stillbay type.

When we come to compare the Northern Rhodesian with the Cape Wilton we see a still greater diversity of types (11). The smaller and more delicately made microliths, the ellipsoidal scraper, the double-backed point, shell crescents, and the pottery clearly distinguish the two. The differences between the Southern Rhodesian Wilton and its later development in the Union are ably set out by Jones in his account of his excavations at Nswatugi and Madilyangwa, and need not be restated here.

Comparing the Mumbwa Wilton with the Wilton cultures Leakey has found in Kenya we find no exact parallels (12). Our industry lacks the double-ended thumb-nail scrapers and pottery of the Kenya Wilton A, neither does it contain the double-backed points or small pressure-flaked points and pottery of the Wilton B.

From this brief examination of the stratigraphical combined with the typological evidence for the age of the various Wilton industries we can conclude that the variety found in the south is undoubtedly later in date than that farther north, and it may be stated with a reasonable degree of probability that as we go south from East Africa the varieties of Wilton encountered are progressively later in date.

One further point of great importance is furnished by skeletal material that has been found at a number of sites in the Union and Rhodesia. Whereas all human skeletal material associated with the Middle Stone Age industries is of the Boskopoid or Australoid types, that associated with the Later Stone Age Wilton and Smithfield industries is predominantly Bush, with a varying degree of admixture with the earlier races. To the best of my knowledge no remains of Bush type have been found with Middle Stone Age material. As it seems extremely unlikely that a sudden degeneration of the large-boned Boskop race at the end of Middle Stone Age times should produce in so short a time a stock so completely distinct

we are driven to consider that the Bush physical type was responsible for the introduction of the new cultural traits into South Africa. At Mumbwa, and also in the Zambesi valley, we have Northern Rhodesian Wilton industries intimately connected with the Bush race, which fact forms corroborative evidence for our theory of a progressive infiltration into the subcontinent of this new microlithic culture.

The second point to determine, if possible, is the origin of the whole complex. In Kenya and Tanganyika Leakey has found the Wilton culture to be stratigraphically later than the Magosian, and we have reason to suspect that this may also prove to be the case in the subcontinent. The obvious line of approach is thus through these two cultures. Are they the direct ancestors of the Wilton, developing along parallel lines into the various local forms of this industry, or was a modification of the indigenous culture brought about through ethnic movement due perhaps to climatic change, or were these cultures entirely superseded by the Wilton without influencing it in any way?

As I have shown above, there is very little distinction between the Stillbay industry from Mumbwa and the typical Stillbay of the south. The slight differences can probably be explained as local variations within a cultural whole. The underlying technique is the same and pressure-flaked points are the outstanding tools. When we compare the Mumbwa Stillbay with the Mumbwa Wilton we find at first sight a number of tool types common to both. The essential difference, however, is one of percentage variation. Whereas the tortoise core and flake with faceted or prepared platform are basic forms in the Stillbay they are absent from the Wilton, where blades are the essential element. Exceptions arise only in rare occurrences of advanced Levallois elements in the earlier phase of the Wilton in Northern Rhodesia. The slender bifaced point, presumably pressure flaked, is absent in the Wilton but is the type-tool of the Stillbay. In Rhodesia backed blades and microliths are rare in the Stillbay and the type-tools of the Wilton. One is essentially a Palaeolithic, the other a Mesolithic culture. The Stillbay points were presumably the stone heads of spears (it is the largest implements that are significant when suggesting the original use of this tool type), while the essential weapon of offence with the Wilton was the bow and arrows with microlithic barbs, thus accounting for the greatest difference—the microlithic nature of the Wilton.

Apart from new types of implement found with the younger industry, if the Mumbwa Wilton had been derived direct from the Mumbwa Stillbay, then it is hardly likely that the point would have entirely disappeared, it would surely have survived in a modified form. Moreover, the backed blades found with the Stillbay can be easily distinguished by their size

and crudeness from those found with the Wilton. The Stillbay crescent or backed blade was produced from a Levallois flake, while those found with the Wilton were made from blades. Evidence (to be published later) from the Zambesi valley shows the Stillbay backed blade to be there a development from crude backed flakes. The very rare examples of pigmy crescent found with the Stillbay look strikingly out of place in such an assemblage.

The advent of the Wilton introduces a number of new tool types however. Firstly, there is the polished stone axe, and associated with this are percussion-flaked chopping tools. It is not generally recognised that the Wilton contains any axe elements, but I consider, as the Table shows, that the axe was a small but intimate part of the Wilton complex. Of all the polished axes that have been found associated with recognisable industries in Rhodesia, all are found with the Wilton. Presumably the percentage of axe elements at any one site would be determined by the prevailing ecological conditions, thickly wooded country requiring a greater percentage than open grassland or scrubland, where axes would be few or entirely absent. It would seem, therefore, that the polished axes were introduced into Rhodesia some time during the Wilton occupation, presumably by the makers of this culture, and were not an autochthonous growth or the cast-offs of casual Neolithic vagrants.

Secondly, there is the bored stone. The only ones that I know of at present from Northern Rhodesia that can be associated with the Wilton come from Mumbwa and a rock shelter at Pandawiri Hill in the Eastern Province. In Southern Rhodesia we have examples from Gokomere and a fragment from Nyazongo. On the other hand, bored stones associated with the Wilton in the Union may well be borrowed from the Smithfield, in which van Riet Lowe has shown them to be a type-tool.

Thirdly, there are certain exotic forms such as the slate palettes, pendants, and various other stone ornaments. Finally, the ostrich egg-shell beads, grindstones, and specialised bone industry are also Wilton introductions.

It has been suggested that progressive desiccation or some other such change in climatic conditions might have been responsible for gradual local development into a microlithic culture. Although climatic changes have no doubt had considerable repercussions on primitive hunting and food-gathering communities I do not consider this to have been the immediate cause of the introduction of the microlithic element into the subcontinent. In South Africa such elements are intrusive, just as they are in Europe. At Mumbwa the ethnic change is too sudden to be due to climatic causation, and, moreover, the developed Stillbay industry was practised by a people living at a time when the climate was drier than in the succeeding Wilton period.

The above points suggest, therefore, that there is no direct connection between the Stillbay and the Wilton; that the one is not the uninterrupted outcome of the other. That they are related, however, seems certainly to be the case. We are faced, therefore, with the task of discovering a parent culture which embodies both elements from the Stillbay and also the new elements found with the Wilton. This parent appears to be furnished by the Magosian complex, which to my mind is the result of hybridisation of the Stillbay with an intrusive element.

I have applied the term Magosian to those industries in South Africa that combine both Middle Stone Age (faceted flake) and Neanthropic (blade and burin) characteristics in their make-up. The East African Magosian finds a striking parallel in the Sawmills industry and in the industry from Parma Kopjie. The average size of the pigmy tools in these industries is almost identical with those from Mumbwa and the Zambesi valley, where, however, the pressure-flaked point is entirely absent. The large trapeziums and backed blades of the Howieson's Poort industry and of that from Montagu cave recall the Northern Rhodesian Wilton tools of this type.

It appears that in all these Magosian types of industry a basic Stillbay or Late Middle Stone Age element has been fused with a new and intrusive culture. From the above brief comparison of these industries with various types of Wilton, which latter are always later in date than the former, it seems clear that these hybrid industries developed into the different varieties of Wilton. This new influence on the Stillbay is attested also by the fact that the Howieson's Poort industry has been proved contemporary with the true Stillbay industry at the Cape, occurring as it does intercalated with the Stillbay in the Skildergat cave. Thus the Stillbay existed in South Africa side by side with a culture which had grown from a fusion of this culture with some new element. This new element shows itself in parallel flaking and the use of blades, the true angle burin, the microliths, including the trapezium and the thumb-nail scraper of the Magosian industries. All these new elements are common to the Wilton industries, and it is thus in the Magosian that we find the key to the Wilton of the subcontinent.

We have then reached the conclusion that the Wilton is a direct descendant of the Magosian, which itself has grown from a fusion of the Stillbay with an intrusive Neanthropic element. The differences in the local varieties of Wilton are due to the fact that the migrating culture was in a more primitive form, for instance at Mumbwa, than when the complex reached Southern Rhodesia and the Union. Thus the Northern Rhodesian Wilton as typified at Mumbwa may be considered as a Proto-Wilton or an early stage in the development of this Neanthropic microlithic complex

in its migration southward. There is no doubt, however, that this culture persisted for some considerable time after its arrival (Lake Tanganyika Wilton with pottery: Bantu tribal legend), and was contemporary with the earlier Wilton industries south of the Zambesi. Owing to the fact that it does not appear to have been in contact with or influenced by pressure of peoples or cultural traits outside its immediate locality, it continued to exist in the comparatively pure form that is found at Mumbwa.

It now remains for us to determine the origins of the culture which as our intrusive element combined with the Stillbay to form the Magosian and later the Wilton.

I should state here that in emphasising the microlithic component in this intrusive culture I do not imply that microliths were the only tools going to make up its stone industry. Larger elements, such as backed blades, burins, etc., are also found, especially in the earlier of the South African hybrid industries, but I stress the microlithic element as I consider this to be the important component. Also the earlier industries contain larger tools than the later, which is possibly due to the fact that they have not developed so far from the immediate fusion of the Stillbay or Late Middle Stone Age making larger implements, and the microlith producing culture.

We have shown that this intrusive culture must have come from the northern part of the continent. If we turn to the north-western side we find no Neanthropic microlithic element, the predominant culture is the Tumbian and its derivatives. In the north-east, in East Africa and Egypt, however, we find microlithic cultures which may have provided this new element. In the present state of our knowledge it seems unlikely that the southern Wilton was an ultimate development from the Kenya Aurignacian or the North African Capsian. If derived from the Capsian it is necessary to suppose a degenerate form persisting to the south after the disappearance of the typical North African Capsian, as the highly geometric forms of the later Capsian are, with the exception of rare examples of the petit-tranchet, quite absent from the southern Wilton. However, it is of interest to note that the bored stone and petit-tranchet are Capsian tools (13), and that the crescent and tranchet persisted into historical times in Nubia we know from its occurrence in a XXV Dynasty tomb (14). Seligman describes a surface site at Jebel Gule in the Sudan which, if homogeneous, might well have given birth to such an industry as the Mumbwa Wilton (15).

A more likely ancestor is the Kenya Aurignacian, but the physical types found with this culture are against this hypothesis unless the Springbok Flats skull can be cited as evidence of penetration by this race into South Africa. Our nearest parallels, both culturally and physically, are with the Magosian and Wilton cultures of Kenya. The essentially

microlithic nature of the Kenya Wilton, together with the presence of a few larger elements, finds a striking parallel in the Mumbwa and Zambesi Wilton industries. Moreover, the physical type found with the Kenya Wilton A may be described as Bush-Boskopoid, and is therefore closely allied to that found with the Wilton in the subcontinent. This physical type cannot have been derived from the Aurignacian, which physically and culturally developed into the Elmenteitan.

When we thus come to compare in detail the Kenya Wilton cultures with the Northern Rhodesian Wilton it does not appear likely that the latter was derived from them. We find our nearest parallels in the Kenya Wilton B derived in like manner direct from the Magosian. It seems more likely that we should consider the Kenya Wilton and the South African Wilton cultures as parallel developments from an original microlithic culture spread.

It is now generally admitted that in Europe the Tardenoisian microlithic elements of the Mesolithic are intrusive and come from North Africa, so that it is not unnatural to suppose that a similar cultural movement to the south may also have taken place, which, of course, need not necessarily be contemporary with the northward migration. Vignard's excavations at Kom-Ombo in Egypt have brought to light an extremely interesting culture—the Sebilian—which he has shown to be originally derived from a Levalloisian ancestry. This culture, which developed through a kind of Capsian into a form of Tardenoisian, is considered by Vignard to be "the parent of all microlithic industries which surrounded and spread out from the Mediterranean basin in Mesolithic times," a theory which Breuil also is prepared to accept (16). It is possible that the Sebilian is itself the result of culture-contact, but in its final form it, or a similar culture, may well have provided the intrusive microlithic element in the Late Stone Age industries of the subcontinent.

To summarise: we are now in a position to give a fairly clear estimate of the affinities of the Mumbwa Wilton with the other southern Wilton industries. We have seen on stratigraphical and typological grounds that as the Wilton occurs southward from East Africa to the Cape it is progressively later in date. It has been inferred from this that the Wilton was an intrusive culture migrating southward at the end of Middle Stone Age times, and practised in all probability by an incoming small race of Bush stock, which mingled with the indigenous population. Culturally we have seen the ancestors of the Wilton to be the local Stillbay combining with an intrusive Neanthropic element, possibly of Sebilian type, migrating southwards from the north of the continent. This fusion produced the Magosian complex out of which grew and developed the Wilton. The position of the Mumbwa industry, and consequently of the Northern Rhodesian Wilton

as a whole, is thus seen to be that of a stage of development in a particular locality of a wide complex of Wilton industries which progressed southward at the end of the Middle Stone Age, and which finally fused with and superseded the existing local industries and persisted with the Bush race in certain parts of the Union of South Africa until comparatively recent years.

In conclusion there are one or two minor points regarding the variety of Northern Rhodesian Wilton found at Mumbwa which it would be of interest to discuss briefly.

One point which may be briefly considered is whether the Wilton people inhabited their caves all the year round or whether the occupation was seasonal or at irregular intervals. This raises the question as to whether the makers of the Wilton had arrived at a neolithic stage of culture. I do not consider the mere presence of polished tools, or even pottery, as sufficient for designating a culture neolithic; the important point is the change in the method of livelihood—from a food-gathering to a pastoral or agricultural community with the domestication of animals, permanent or semi-permanent settlements, and primitive forms of agriculture. We have no evidence to associate any of these practices with the Wilton; the fact that caves formed semi-permanent homes cannot, of course, be used to argue this point. As far as we are able to tell, the Wilton folk were a typical mesolithic, food-gathering people, following the seasonal migration of game as do their descendants, the Bushmen, to-day. They were dependent therefore, firstly, on the game that they could shoot or snare, and, secondly, on the edible vegetation—the latter being particularly abundant during the rainy season.

The faunal remains from the Wilton zone at Mumbwa are typically grassland, showing very little variation from that found in the district to-day, where there is also a very distinct seasonal migration of game (17). During the dry season, from May to October, the game are collected in very large numbers in the Kafue Flats, where the main, if not only, supply of water is to be found; during the rainy season the gregarious animals disperse and wander in towards the central plateau. We should expect, therefore, that the population would follow the game, whose departure from the Kafue Flats would more or less correspond with the first vegetable harvest. The Kafue is not more than sixty miles to the southward of Mumbwa, and during the latter part of the rainy season the Flats are flooded and unfit for human habitation. Now fig. 1 clearly shows that by far the easiest and perhaps the only routes that could be followed were down the river valleys or over the Upper Valley soil with its open grassland vegetation. The Southern Plateau soils form an effective barrier to a people whose material culture is adapted almost entirely to grassland. To turn to the caves

themselves—which, not being liable to flooding, were habitable the whole year round. There is no evidence that the cave was abandoned for any length of time during the Wilton occupation, and no layers sterile of implements were found. We did find, however, that distributed fairly evenly throughout the deposit were certain bones that had been gnawed by a large rodent—Dr. Broom suggests porcupine. Now this can hardly have happened while the cave was occupied by men, nor did it occur in recent years, as the marks are equally fossilised with the bone; it must therefore have happened at a time when the cave was temporarily vacated. The presence of teeth of hyena may also be evidence of this. Moreover, when a burial had taken place the cave-dwellers presumably moved elsewhere, as a certain fear of contact with the dead is prevalent in every social community, however primitive. The Unio shells may signify contact with the Kafue, as all the rivers running from the plateau in the neighbourhood of Mumbwa have seasonally dry watercourses. Evidence from the faunal remains is indefinite, but the greater number come from fully grown animals. The sun-dried clay, if indeed it came from crude shelters, would have provided additional cover during the rains. In the Zambesi valley we have two distinct types of habitation site—the one covering a fairly extensive area and containing numerous microliths, a certain number of scrapers, and occasional axe implements; the other covering only a very small area and containing microliths, but very rarely any scrapers or axes. In the valley itself the former type of site is rare; I would place the Mumbwa site in this category.

The above points suggest that there were occasions on which the Mumbwa caves were temporarily vacated, but whether this was of seasonal occurrence it is not yet possible to determine; if such was the case, then it was probably a wet season site. In view of the fact that seasonal migrations form an essential part of the social life of existing food-gathering peoples I think the possibility of such in Late Stone Age times in Rhodesia should be borne in mind.

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Summary of Conclusions.

The sequence of events in the Mumbwa caves was as follows:—

1. Decomposition of bed-rock and formation of a black gritty earth possibly containing evidence of human occupation in Cave 2.
2. Deposition of an aeolian red "clay" during an arid period. Caves uninhabited.
3. A seasonally dry and wet climate resulting in the deposition of the red lower cave earth and the cementing of the hardened complex. Caves inhabited by the makers of the Rhodesian Stillbay industry.
4. An increase in wetter conditions during which the black upper cave earth was deposited. Caves inhabited by the makers of the Northern Rhodesian Wilton culture.
5. At some period subsequent to this the caves were inhabited by people practising an Iron Age culture.

In the discussion on the affinities of the Northern Rhodesian Wilton it has been suggested that this culture is the direct derivative of the local form of Magosian industry, which in turn was the result of hybridisation between the local Stillbay and an intrusive Neanthropic culture first appearing at the very end of Middle Stone Age times.

The question of seasonal occupation of the caves has been touched upon, and some, although no very definite, evidence was adduced in support of it.

Acknowledgments.

I should like to express my most sincere thanks to all those who have made this publication possible. To Mr. A. W. Bonfield for his kindness

and assistance during our stay at Mumbwa; to the Rev. Neville Jones for allowing me a completely free hand to examine his excellent Wilton collections in the Bulawayo Museum; to Dr. F. E. Zeuner for analysing the soil samples and for his valuable report; to Mr. J. F. Schofield for his drawings of the pottery and for his welcome collaboration in the Iron Age section; to Dr. R. Broom for his report on the faunal remains; to Dr. K. H. Barnard for examining the mollusc remains; and to Major B. Lightfoot for reporting on the pigments and materials used. I also owe a debt of gratitude to the members of the Italian Scientific Expedition who pointed out the possibilities and importance of the Mumbwa caves, and whose sections there rendered us valuable assistance. To Professor C. van Riet Lowe I am particularly indebted for his most valuable comments and for his kindness in communicating this paper on my behalf. Finally, I must acknowledge the very considerable debt to my wife for the illustrations of the stone implements.

The Council desires to acknowledge the receipt of a grant from the Trustees of the Rhodes Livingstone Institute towards the cost of publication of this paper.

Appendix I.

Dr. R. Broom, F.R.S., has kindly identified the following species:—

Area II.—0 to 1 foot Iron Age Culture.

Carnassial, large Dog—*Canis familiaris.*
„ small „ — „ „
Worn Carnassial, small Jackal—*Thos adustus* probably.
Tip third incisor, *Hyaena brunnea.*
Lower first molar, *Cercopithecus* sp.
Molars, *Orycteropus.*
Three teeth, *Porcupine.*
Premolars and molars of Warthog.
Fragment incisor, *Thryonomys* (Cane rat).
Two upper molars, apparently *Connochoetus taurinus.*
Two teeth reedbuck (*Cervicapra*).
Teeth of Duiker (*Cephalophus*).
Fragment lower molar probably of Domestic Ox (*Bos taurus*), not Cape Buffalo.

Area I.—1 to 3 feet Wilton Industry.

Mainly fragments of Warthog molars and a few Antelope fragments.

Area II.—1 *to* 3 *feet Wilton Industry.*

Kudu.
Duiker (*Cephalophus*).
Wildebeeste (*Connochoetus taurinus*).
Porcupine.
Warthog.
Equus teeth.
Roan Antelope (*Hippotragus equines*).
Eland (*Taurotragus Oryx*).
Reedbuck (*Cervicapra*).

Area I.—3 *to* 7 *feet Stillbay Industry.*

Upper and lower molars, *Equus* (? Zebra).
First lower molar, *Hyaena brunnea.*
Reedbuck (*Cervicapra*).
Hartebeest (*Bubalis*).
Milk molar, unidentified.
Warthog.

Appendix II.

A number of fragmentary mollusc remains were recovered from the Upper Cave earth containing the Wilton industry. These were submitted to Dr. K. H. Barnard, who replied as follows:—

Dear Sir,—

I am returning the box of shells from the Mumbwa caves.

The upper layer in the box contains two specimens (1 juvenile) and fragments of a species of *Achatina.*

The lower layer contains fragments of *Unio* (section *Cafferia*) (probably either *caffer* or *mossambicensis*).

In one pill-box is a juvenile of a different species of *Achatina*, and in the other a species of *Thapsia* or *Gudeëla* (family *Helicarionidae*).

The *Unio*, of course, is a river bivalve shell. *Achatina* and *Thapsia* (or *Gudeëla*) are both characteristic of tropical and subtropical regions. *Achatina* extends into the N.E. parts of Ovamboland and the Kaokoveld, but not beyond the 16–18 in. isohyet. I think you might say that the climate at the time of the Mumbwa deposits had at least a 20-inch rainfall.

I am sorry I cannot put specific names to the shells. It would be better not to use one for the *Unio.*

(Signed) Keppel H. Barnard.

Appendix III.

The following is Major B. Lightfoot's report on the pigments and other material submitted:—

Dear Sir,—

With reference to your letter of the 20th April herewith a few notes on the species you sent.

(1) (Here follows a list of fifteen specimens of stone and rock used for making implements which have been identified as follows. Four quartz, six chalcedony—three weathered. Two hornstone. One quartz-zoisite rock. Two ferruginous quartzite.—J. D. C.)

(2, 4, and 5) I have made little tablets of the pigments. The colours these most resemble are given below according to the Unesma colour chart. They are obtained mainly from haematite, limonite, and graphite schist.

Wilton Zone.—4 ic (i): 5 ic (i): 3 la (2): 5 ni (i)
4 ig (1): 5 pi (1): 6 pl (1).

Stillbay Zone.—5 le (1): 5 ge (2): 5 lg (1): 5 ig (1)
2 ga (1): 4 g (1): 4 ge (1).

(3) With regard to the round balls: one is undoubtedly haematite. The others are weathered and could not be determined without destroying them. The best we can do is to take their specific gravities.

M1 B4 L9 has a specific gravity of 2·7
M1 A4 L9 ,, ,, ,, 2·75
M1 A3 L8 ,, ,, ,, 2·64.

Powder shows mostly iron oxides and a little amphibole. I think these are weathered dolerites.

(6 and 7) I should not like to express any opinion about the clays.

They are similar to the stuff left after kaffir huts have been set on fire or collapsed.

The M1 clay is a darker red than the M2, and I think burnt clay is about as far as one could go.

(Signed) B. Lightfoot,
Director, Geological Survey.

Appendix IV.

(Written in the Field.)

Since this paper was written I have been able, while serving with the East African Forces, to examine at first hand the microlithic cultures of

Kenya (thanks to the kindness of Dr. L. S. B. Leakey), British Somaliland, and Abyssinia. This has helped to confirm and strengthen my belief in the evidence that I have put forward above of a migration from north to south through the continent of a true microlithic culture in Late Stone Age times. That this migration was in the nature of a gradual absorption and fusion of the new culture with those already established in the various areas that have been examined, rather than a sudden transition, is shown by the very nature of the microlithic industries themselves. We cannot turn to any one microlithic culture of north or east Africa and point to it as being the parent of our Rhodesian Wilton for these are all local variations and, as such, are only of local distribution. They are the product of the borrowing and fusion of the intrusive microlithic element with the previously existing culture of the particular locality. For example, contact between the culture which developed from the Kenya Aurignacian and the microlithic culture-spread has produced the Kenya Wilton A with its pottery, double-ended thumbnail scrapers and micro-burins; on the other hand fusion with the Kenya Stillbay has produced, in the early stages of assimilation, the Magosian, and in the later the Kenya Wilton B. The same appears to have been the case in Uganda, and there are signs that the Egyptian Sebilian underwent a similar change. In Somaliland and eastern Abyssinia, on the other hand, where the Neanthropic Aurignacian appears to be intrusive and the predominant culture was the Stillbay, absorption by the microlith-using immigrants resulted in industries akin to the Wilton B of Kenya. A similar state of affairs can be seen in Central and South Africa where the blade and burin culture was also absent. Here again a gradual fusion of the intrusive microlithic culture, which had already assimilated foreign characteristics from culture-contacts farther north, with the local variants of the Stillbay complex produced the Rhodesian and South African Magosian and Wilton cultures. (The time element of course has further emphasised local variation.) On the other hand in the southern parts of the Belgian Congo, where the Wilton culture does not appear to have penetrated, the local culture was free to develop unhindered by any introduction of microlithic elements.

The new evidence from Somaliland and eastern Abyssinia points yet again to the north-western part of the continent as being the centre from which the microlithic complex was diffused. The migration from thence northward to western and southern Europe, taking place as it did at an earlier date than that southward towards the sub-continent, again presents similar evidence of assimilation, as well as of extensive influence on the existing cultures of those parts. Yet this influx of a microlithic culture, termed in Europe the Tardenoisian and in South Africa the Wilton, apparently attained a greater degree of homogeneity in its final development

in the northern continent. The culture sequence in the Grotte des Enfants, Mentone, is one example indicating gradual infiltration and supersession; here, of the Late Aurignacian (Châtelperronian) by the Tardenoisian. The Azilian would appear to be the result of fusion with a late and degenerate Magdalenian but with elements of the latter culture predominating. The microlithic element in the Maglemose culture of the northern seaboard and the cultures of the Litorina maximum is thought to have been introduced by contact with the intrusive Tardenoisian. Whether the parent of the microlithic cultures which spread from North Africa to Europe and southward to East and South Africa was a developed form of Late Capsian must unfortunately remain conjectural until the archaeology of the northern and central Sahara and West Africa is more perfectly known.

(Signed) J. D. Clark.
10/9/41.

EXPLANATION OF PLATES.

Plate XV.

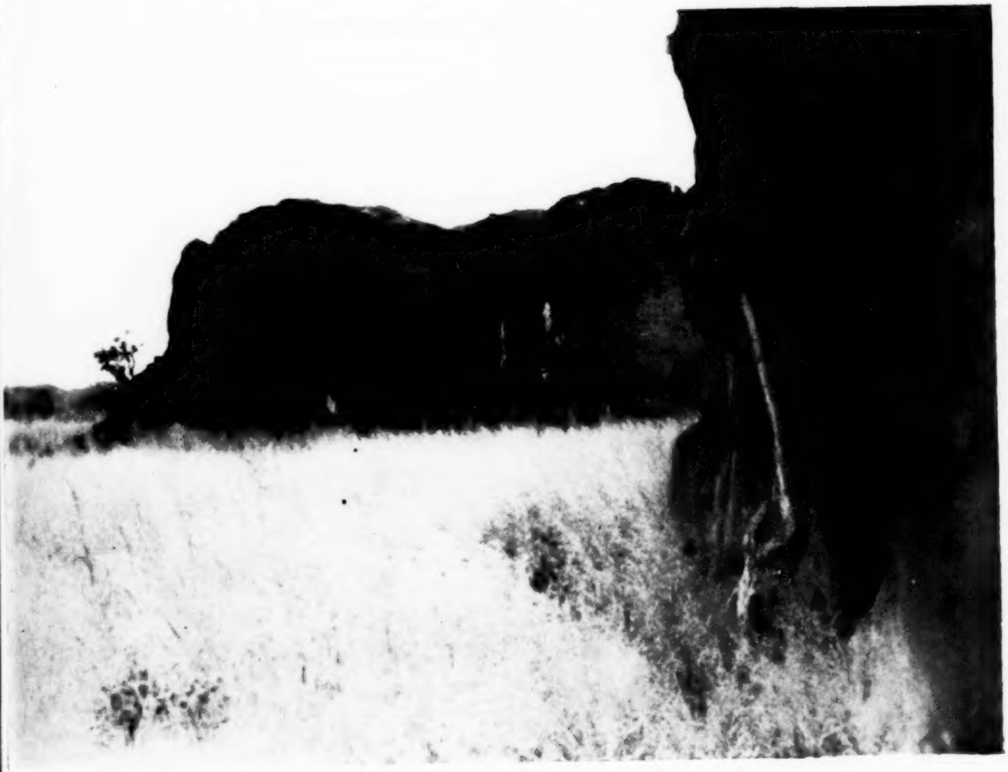
Showing the main northern extension of the limestone bluffs in which the two larger caves are situated. The grass growing on the black alluvium is 8 feet high. The tree in the centre hides the entrance to Cave 1.

Plate XVI.

Shows Area I taken down to bed-rock at 9 feet 3 inches. From the top to the third label down is the Iron Age level, from the third to the fourth label the Wilton zone, from the fourth to the fifth the Stillbay zone, from the fifth to the sixth the sterile red clay, from the sixth to bed-rock the decomposed rock and gritty black earth.

Plate XVII.

Shows Area II taken down to the 2-foot-6-inch level. The black Upper Cave earth containing the Iron Age and Wilton industries can be seen banked up against the hardened complex in the red earth at the left end of the section adjacent to the cave wall.



J. D. Clark.

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THE ASSOCIATED FAUNA AND CULTURE OF THE VLAKKRAAL THERMAL SPRINGS, O.F.S.

I. Introduction. By L. H. Wells and H. B. S. Cooke.
II. The Stone Age Industry. By B. D. Malan.
III. The Faunal Remains. By L. H. Wells and H. B. S. Cooke.

(With twelve Text-figures.)

(Read April 16, 1941.)

I. Introduction.

The farm Vlakkraal lies about twenty-five miles north-north-west of Bloemfontein, a few miles west of the road to Saltpan and a little south of the Modder River. It is only five miles in a direct line south of the well-known curative springs of Floris Bad, but the latter site lies on the opposite side of the Modder River and farther from it. To the south of the home-steads on Vlakkraal there occurs a wide and shallow depression in which several "eyes" of thermal springs are to be found.

The presence in one of the Vlakkraal springs of a gravel and sand deposit containing artifacts and fossil remains was originally discovered when this spring was being cleared and enlarged for agricultural purposes. This discovery naturally attracted the attention of Professor T. F. Dreyer who was at that time engaged in his work on the nearby Floris Bad site. In 1931–32 the deposit was extensively worked, partly under the supervision of Professor Dreyer, and a large part of the collection obtained consequently went to Bloemfontein. However, through the agency of Dr. C. H. Roux (a relative of the owner of the farm, Mr. M. A. Prinsloo), a representative collection was deposited in the Department of Anatomy, University of the Witwatersrand. This collection was augmented by further material collected in 1939 by Mr. J. F. Hartman and in 1940 by the present authors.

Dreyer's only published references to the Vlakkraal site occur in his paper on the archaeology of the Floris Bad deposit (1938), in which it is mentioned under the name "Prinsloo site." He speaks of the deposit as an unstratified accumulation of spring debris occupying a hole in the shale and refers briefly to the industry, figuring a small number of artifacts. The faunal remains were not described, but it is stated incidentally that

the industry is associated with the same fossil species as are found at Floris Bad.

Recent work on problems of the South African Quaternary faunas and their correlation with the archaeological sequence has redirected the attention of the authors to the Vlakkraal material in the Witwatersrand collection. The examination of the artifacts by Mr. B. D. Malan of the Bureau of Archaeology has also shown that the industry represents a very homogeneous cultural phase. We have therefore considered the material from this site as worthy of an independent and detailed analysis since it appears to yield for the first time in South Africa the reliable association of an extensive fauna with a Middle Stone Age industry. The faunal remains, moreover, suggest a reconsideration of views expressed both by Dreyer and Lyle and by other commentators upon the specific identity of various forms occurring in the Floris Bad fauna.

A fortunate circumstance has increased our opportunities for this study by making available some specimens belonging to the South African Museum, Cape Town. This material was included in the extensive collections of fossil mammalian remains from southern Africa which have been loaned to one of the authors (H. B. S. C.) in connection with certain work on the fossil mammalia upon which he is engaged. A number of teeth of wart-hogs and horses obtained from the Vlakkraal site are present in the S.A. Museum collections; presumably they were presented to that museum by Professor Dreyer, whose specific identifications they bear. Some of these specimens are labelled as coming from the "Prinsloo site," while others have proved to be parts of the same individuals as specimens in the Witwatersrand collection.

When the farm was visited by the authors in 1940 the springs from which our material was derived was an almost circular pool about 30 feet in diameter. This depression is an artificial one and surrounding it is a ring of the sandy material excavated in its formation. It is from this debris that artifacts and fossils were recovered. The waters bubble up near the centre of the pool and are led off through a channel for agricultural purposes. The temperature of the water is not high and there does not appear to be much dissolved gas, though a slightly brakish taste is perceptible. Nothing can be seen of the stratification in the area of excavation, but the debris does not suggest any unusual features. According to verbal information from Mr. Prinsloo, the upper layers consisted of sand, and gravels were encountered some few feet below the surface.

This particular spring is not the only one, for several other "eyes" occur in the immediate area, though these are all apparently smaller. None of them has been so extensively developed, but such as were excavated did not apparently yield any recognisable remains. Together with the

larger spring, these smaller ones occupy a depression in the shaly rock of the district, and the floor of this depression is covered by dirty white muddy sands. It would appear that the springs now represented by small and scattered "eyes" at one time formed part of a moderately large single pan with several centres of spring activity. Pans of this sort are numerous in the area and to the north, and there is little doubt that they were at one time larger and more widespread.

It would not be profitable at this juncture to comment on the precise origin or possible development of these springs, for the available data are of the scantiest. There seems little doubt, however, that the Vlakkraal site, Floris Bad, and many other similar springs are closely related in development and probably more or less contemporaneous. Experience elsewhere has shown the transitory nature of many such thermal springs, and it is more than probable that some were much longer lived than others. The artifacts represent only a single cultural phase, whereas Floris Bad apparently shows a sequence of cultures, one of which is the same as that from Vlakkraal. In view of the proximity of these two sites it is reasonable to infer that the occupation at Vlakkraal was shorter than that at Floris Bad. The deposits at Vlakkraal are also much thinner than those of Floris Bad, and it may well be that the spring itself remained stable and useful only for a relatively short time during the later Middle Stone Age.

II. The Stone Age Industry.

Materials.—The material used in all specimens except faceted polyhedral spheres and true spheres is indurated shale. It has been well indurated and is shiny black in colour. The majority of specimens are weathered to a slaty grey, the degree of penetration of the weathering varying considerably. A few specimens have a shiny glaze as a result of the minerals contained in the water of the spring in the eye of which they were found. Faceted polyhedral and true spheres are made either of igneous rocks or of very hard sedimentary rocks.

Technique.—Underlying the manufacture of all the tools is an advanced Levallois technique. Convergent longitudinal primary flaking and careful preparation of striking platforms, characteristic of this technique, is present in the great majority of specimens. Radial primary work on flakes is rare. The collection is unfortunately deficient in cores, only four being present, and these are all of radial "disc" type. The larger points in the collection were derived from cores considerably larger than any that have been found, and one core is considerably smaller than any of the implements.

Secondary trimming is steep and does not extend far over the face of the implements. On the other hand, step-flaking is rare.

Description of Artifacts.

(1) *Cores.*—The collection contains only four cores. All are typical radial "disc" Levallois cores and have been struck. The largest has a diameter of 6·5 cm., the smallest measures 2·5 cm.

(2) *Points :* (a) *Unworked* (fig. 1 (1)).—A number of slender triangular flakes showing convergent longitudinal flake-scars have not been trimmed after being struck from the core. There is no reason why they should not be regarded as complete tools. The largest is 9·6 cm. long × 4·4 cm. at its broadest part near the butt, at which point it is 1·2 cm. thick. Proportions of length to breadth vary considerably. The broadest specimen is broken, but must have measured 10·9 cm. × 6·3 cm., while the narrowest measures 6·3 cm. × 1·4 cm.

(b) *Trimmed* (*Upper Face*) (fig. 1 (2)).—These may be trimmed along both edges or along the left-hand or right-hand edge only. The secondary flake-scars are not deep and the edges of tools are consequently straight. Sizes vary considerably. A typical large specimen is illustrated, and measures 11·5 cm. × 4·2 cm. × 1·1 cm. A smaller group vary in length from about 7 cm. to 4·3 cm. Included in the latter group is a series of tools with high-keeled points and very steep trimming near the points. The cross-sections of these points near the tip are isosceles triangles the apices of which are angles of 30° and less (fig. 2 (2), (3)). One of these has a carefully reduced bulb of percussion (fig. 2 (3)). Two points, heavier and cruder than the others in the collection, may be referred to the Hagenstad Variation or to the Swartfontein industry (van Hoepen, 1939 *a*), if these latter do not refer to the same cultural expression.

(c) *Trimmed* (*both Faces*).—Several points show reduction of the bulb of percussion (fig. 2 (1), (3)), and a few show work elsewhere on the flake surfaces (fig. 4 (1)).

(3) *Bifaced Point* (fig. 3).—One specimen is completely trimmed over both faces in the manner of a Still Bay lancehead. Nothing remains of either of the original surfaces of the flake. The secondary flake scars are all shallow, such as are expected when a "pressure" or "wood on stone" technique is employed. There is, however, rather more "stepping" than is usually associated with trimming of this kind, possibly on account of the more resilient nature of the material (indurated shale), compared with the silcrete of which such tools are usually made in the Still Bay culture (Malan, 1938). The butt of the flake has been trimmed to a point. The outline of the tool is symmetrical, and the cross-section at all points is lenticular. The tip of the point is missing, but the tool when complete must have measured slightly over 12 cm. in length. Its greatest width is

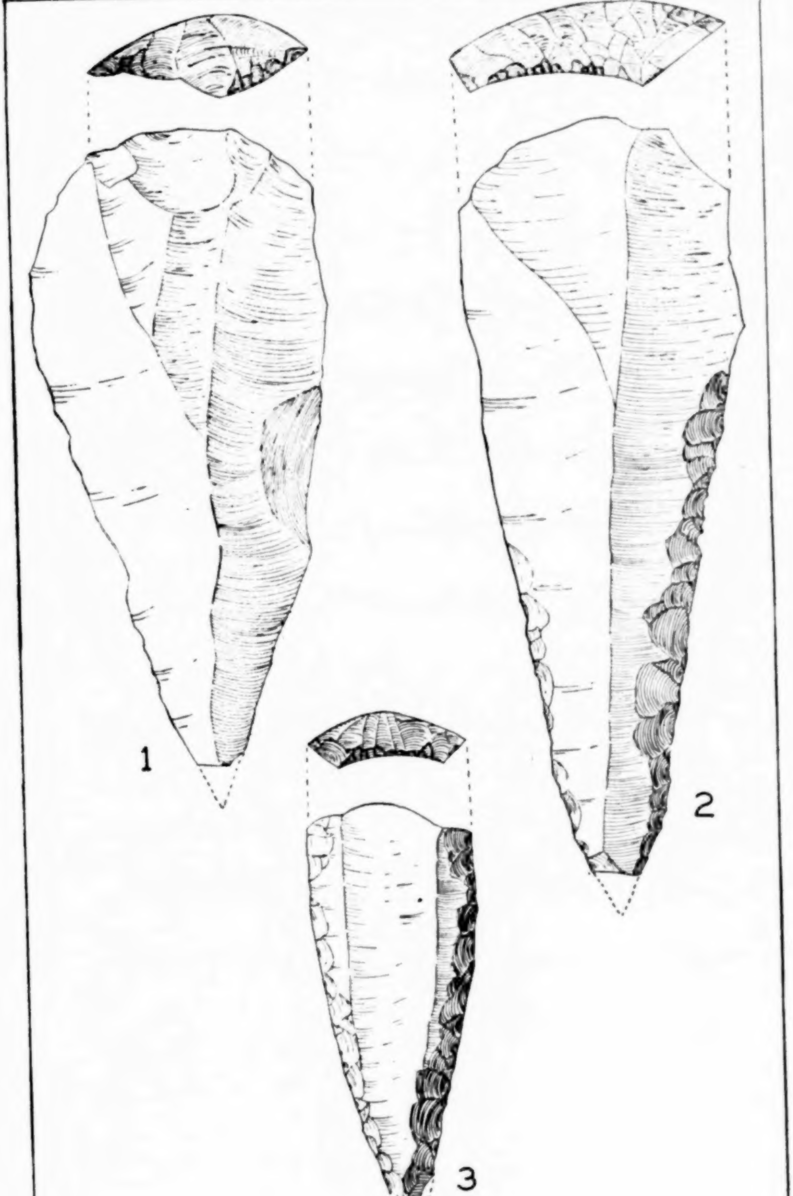

Fig. 1.

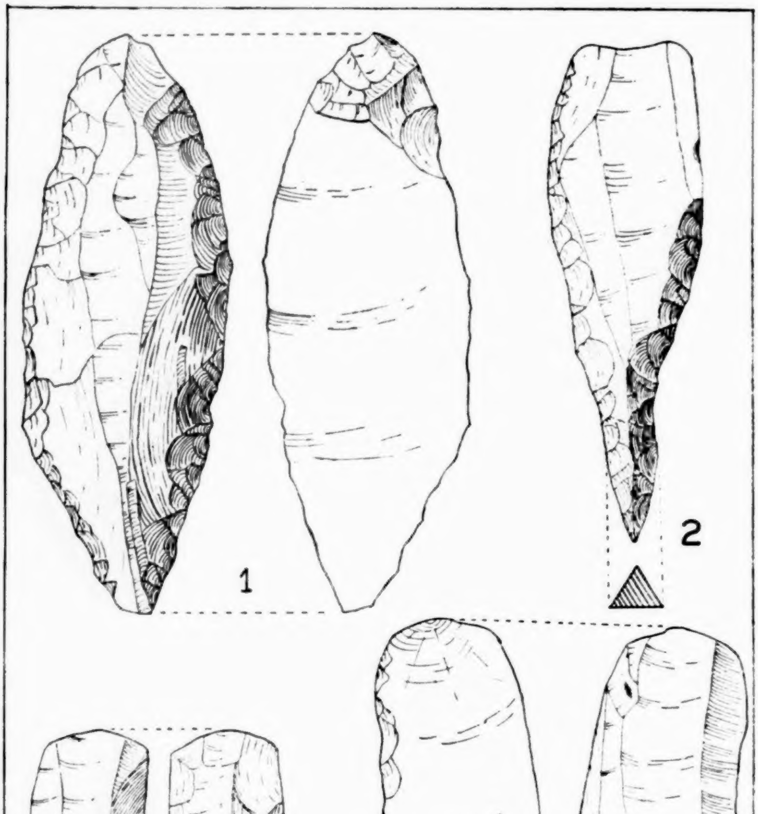

Fig. 2.

3·7 cm. and the maximum thickness 1·5 cm. It is slightly thicker than similar tools in the Still Bay culture.

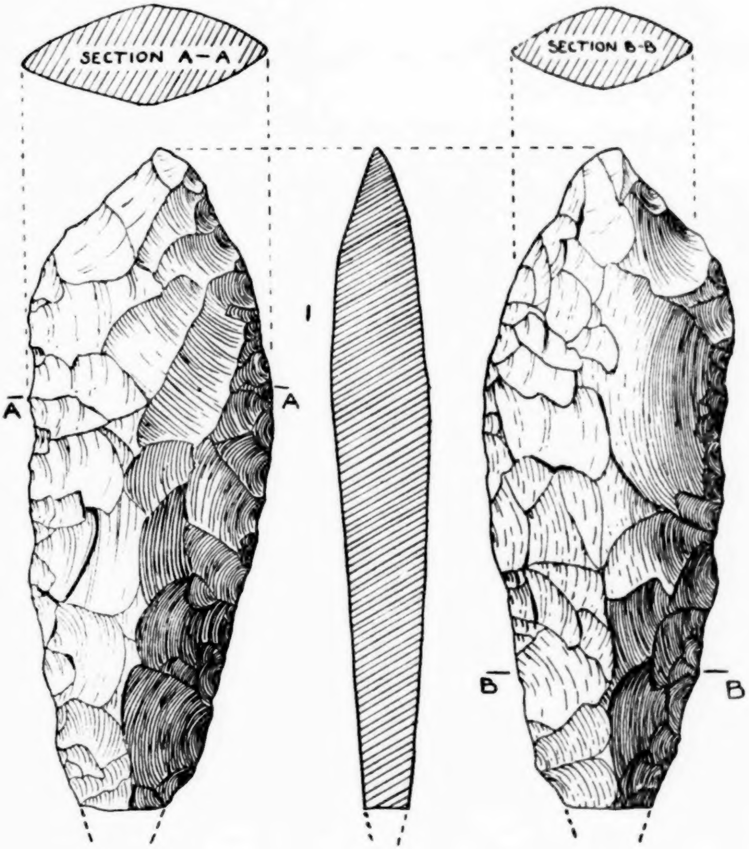

FIG. 3.

(4) *Side-scrapers* (fig. 4 (4)).—A number of flakes have been trimmed along one or both edges to form typical side-scrapers. The largest of these is illustrated and has a reduced bulb of percussion.

(5) *Side-scrapers Trimmed on Flake Surface* (fig. 2 (4)).—A considerable number of these flakes showing trimming on the flake surface occur. They differ from "Kasouga" flakes (Hewitt, 1933) in that the majority are

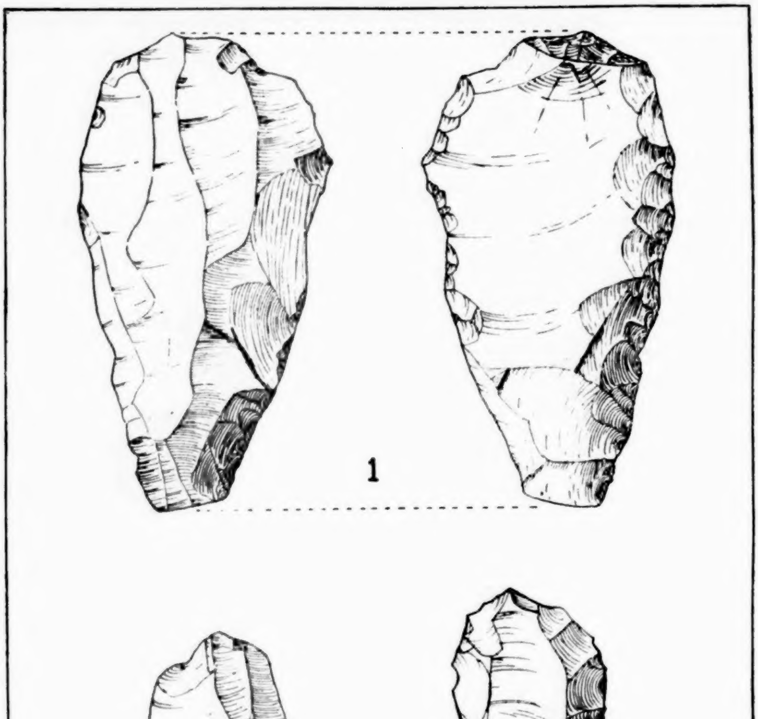

FIG. 4.

larger and thicker, and the trimming does not extend far over the flake surface. This work is in most cases accompanied by trimming of the upper face along one edge, though some specimens show no secondary work on the upper face. In a number of specimens the secondary work on the flake surface is so slight as to suggest that it is the result of damage through use rather than deliberate trimming.

(6) *End-scrapers.*—Three types of end-scrapers occur in the collection: (1) Levallois blades on which the end remote from the striking platform has been trimmed, (2) one specimen of a "duckbill" end-scraper (fig. 4 (2)), and (3) a number of butt-end scrapers in which the striking platforms have been trimmed after removal of the flake from its core. This occurs characteristically opposite a concavity left by a negative flake scar on the upper face of the flake. This feature is often found on flakes which also served the purposes of point or side-scraper (fig. 1 (2), (3)).

(7) *Hollow Scraper.*—There is one hollow scraper in the collection. It is on a slender Levallois flake and the secondary work forming the hollow is on the flake surface of the tool.

(8) *Serrated Scrapers.*—These are rare, but a few are present. The secondary flakes along the edge of Levallois flakes are widely spaced so that the secondary negative bulbs form indentations or serrations, giving a saw-like edge (fig. 4 (3)).

(9) *Burins.*—A heavy side-scraper shows a facet at the tip on the flake-scar surface which closely resembles a burin facet. The specimen is, however, doubtful, though it could have been used as a burin.

(10) *Faceted Polyhedral Stones.*—Although the collection is small, it contains no less than nine faceted polyhedral stones. The largest is the size of a tennis ball; the smallest the size of a golf ball. None of the specimens is made of indurated shale, which is used exclusively for all the other artifacts in the collection. In two of the specimens the ridges between the facets have been worn down either by an abrading or a pecking technique, so that they present a stage in the manufacture of artificial spheres from faceted polyhedral stones.

(11) *Spheroidal Bolas.*—These are artificially rounded spheroids, apparently made from faceted polyhedral stones, but no signs of the faceting remain. One specimen has been split in half. They are approximately the size of tennis balls.

Discussion.

The foregoing descriptions are brief. It has not been necessary to describe the collection in greater detail, since the object of the description is to demonstrate the identity of the material with that which Dr. van Hoepen (1932 *a*) has described as "Die Mosselbaaise Kultuur," the type

site of which is at Mazelspoort (van Hoepen, 1939 *b*). The only types described above and not mentioned by van Hoepen are the bifaced point and the hollow scraper. Types described by van Hoepen but not found in the present collection are undoubted burins, "chatelperron" points, trimmers, and "flaying-knives," *i.e.* concavo-convex scrapers.

Except for his failure to recognise the Levallois technique and the significance of Levallois cores at that time (1932), van Hoepen has given a detailed and meticulous description of exactly analogous material. The present writer has had an opportunity of seeing the type material from Mazelspoort, and the Bureau of Archaeology in Johannesburg has a small collection from the same site presented by Dr. van Hoepen in 1938. Comparison of the Vlakkraal material with the Bureau of Archaeology collection and my acquaintance with the material in the National Museum in Bloemfontein bear out the identity of the culture represented at Mazelspoort and Vlakkraal, sites some thirty miles apart in a direct line. Dreyer (1938), who has figured a few specimens from Vlakkraal (his "Prinsloo site"), has also remarked on their general resemblance to the "Mosselbaaise Kultuur" of van Hoepen.

In 1926 van Hoepen described certain Middle Stone Age material from Mossel Bay under the name "Die Mosselbaaise Kultuur." This was adopted by Goodwin (1928) and incorporated in his paper on the Middle Stone Age (1929), where he establishes this material as the Mossel Bay Variation of the Middle Stone Age.

Three years later van Hoepen (1932) described an extensive collection from Mazelspoort also under the name "Mosselbaaise Kultuur," but without showing any identity of culture between this site and those at Mossel Bay and its environs. It is necessary to indicate some of the differences between the material from Mossel Bay and that found at Mazelspoort.

(1) The Mossel Bay material is characterised by a primary stepped flake on the upper surface of flakes, which Goodwin (1929) has suggested was deliberate, even possibly to facilitate hafting. This feature is not described from Mazelspoort, nor was it observed in the collections in Bloemfontein. It does not occur in the collection in the Bureau of Archaeology, and is absent also from the Vlakkraal material.

(2) The Mossel Bay specimens include a number of tools on Levallois flakes, broad in relation to their length, which have been trimmed into what Goodwin has called "oakleaf" types. These are extremely rare at Mazelspoort.

(3) The secondary work on specimens from Mazelspoort is far more elaborate than anything found at and near Mossel Bay, where the simplicity of secondary work and abundance of tools without secondary trimming is characteristic.

(4) The abundance of faceted polyhedral spheroids at Mazelspoort is most striking compared with their extreme scarcity at Mossel Bay.

(5) The most characteristic tools from Mazelspoort are such points as are described in (2 (*b*)) under "Description of Artifacts" above. These types do not occur at Mossel Bay.

(6) No bifaced lance-head types have been found at Mossel Bay.

In one of the publications referred to above van Hoepen (1939 *b*) mentions the differences naturally found between all sites, and deplores the application of different cultural names to sites showing differences in culture which are not really significant. With this no one will disagree, but we cannot agree that the differences between the industries of Mazelspoort and Vlakkraal on the one hand, and the industries found at and near Mossel Bay on the other, are sufficiently insignificant to justify the application of one cultural name to both. This view is held also by Goodwin.

It is for this very reason that the term "Variation" has been introduced into our literature, to cover cases where differences are not sufficiently great to justify a division into separate cultures.

It is now clear that the "Mosselbaaise Kultuur" described by van Hoepen, the type site of which is at Mazelspoort (and the Vlakkraal material), cannot be identified with the industries from Mossel Bay originally described by van Hoepen as a "Culture" and modified by Goodwin into a "Variation." This is tacitly admitted by van Hoepen in a recent publication (1940) where he states that the Mosselbaaise Kultuur consists of two industries, viz. the Mazelspoort industry and another, the Swartfontein industry. His omission of the industries from Mossel Bay as falling within the "Mosselbaaise Kultuur" is striking.

It is difficult to see any justification for the retention of the name "Mosselbaaise Kultuur" for material the type site of which is at Mazelspoort, near Bloemfontein, some 430 miles in a straight line from Mossel Bay, and which differs markedly from the industries at Mossel Bay and its vicinity. This culture should therefore be renamed, and the name Mazelspoort Culture suggests itself.

The status as a culture (as apart from an industry or variation (Burkitt, 1928)) of what van Hoepen has described under the unfortunate term "Mosselbaaise Kultuur" from Mazelspoort now appears to be established in view of its occurrence at Mazelspoort, Swartfontein, and at Vlakkraal.

The confusion which exists over the nomenclature discussed above is not an isolated case, and much wider problems of terminology await agreement between archaeologists. That this is fully realised is shown by the resolution of the South African Museums Association to request the South African Association for the Advancement of Science to convene a conference for the purpose of discussing problems relating to nomenclature and

terminology in South African Archaeology. It is to be hoped that effect will be given to this recommendation as soon as circumstances permit.

III. The Faunal Remains.

The fossil material consists principally of teeth, but also includes complete and fragmentary limb bones, partial horn-cores, skull fragments, and vertebrae. All these remains are petrified in a characteristic manner, and their interstices are filled with partially consolidated ferruginised sand. Most of the specimens bear a distinctive polish, which appears to be due to some chemical action rather than to abrasion. Their colour varies, the majority being a light brown, but some are blue-black, while others are almost white. In all these features there is a close resemblance to the fossil remains from the Floris Bad site.

Class PISCES.

Two fish vertebrae and a fragment of cranial bone are included in the material. The cranial fragment appears to belong to a species of Barbus, and it is probable that all these remains are to be ascribed to this common South African fresh-water fish.

Class AVES.

The presence in the fauna of an Ostrich (*Struthio* sp.) is attested by several fragments of egg-shell. These do not present any obvious signs of human handiwork, and are therefore included as part of the fauna rather than of the industry.

Class MAMMALIA.

Order Rodentia: Suborder Hystricomorpha.

This group of Rodents is represented by a single heavily worn molar tooth. The crown of this tooth, which is nearly circular, measures 6·5 mm. in diameter and bears three isolated islets of enamel (fig. 5 (1)); the greatest height above the cingulum is 5 mm., with three very short roots and a longer one (fig. 5 (2)). It has not been possible to assign this tooth to any particular type. While its general structure is suggestive of the molar of Hystrix, it is very much smaller in diameter than either the milk or the permanent molars of any recent South African porcupine. On the other hand the tooth cannot be ascribed to Pedetes or Thryonomys, or indeed to any other South African Rodent of which we have been able to examine the dentition. At the same time, we cannot feel ourselves justified in describing it as a new species, although this may ultimately prove to be the case.

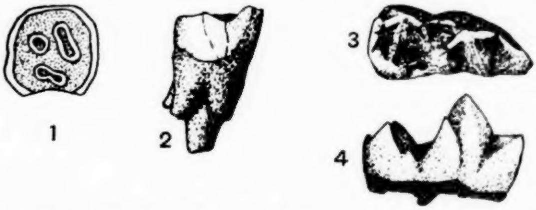

FIG. 5.—(1) Occlusal and (2) lateral views of molar tooth of unidentified Hystricomorph rodent. (3) Occlusal and (4) lateral views of lower first molar of cf. *Cynalopex chama*. (All twice natural size.)

Order CARNIVORA.

The carnivore remains in the collection are extremely few and fragmentary, yet they appear to represent three widely diversified forms, a Hyaena and probably two Canids.

Cf. *Crocuta crocuta* (Erxleben).

A lower right third incisor tooth appears well within the range of variation of the living Spotted Hyaena. It is definitely not that of the Brown Hyaena, the form reported by Lyle (1931) from Floris Bad.

Cf. *Cynalopex chama* (A. Smith).

There is in the collection a lower left first molar which is unerupted and has incompletely formed roots. This tooth from its general morphology is undoubtedly that of a very small canid. Among living forms it agrees very closely in size with the Chama Jackal, being considerably smaller than any of the other Jackals. However, it differs from the living material at our disposal in the greater breadth of the talonid relative to the trigonid, and in the sharper development of certain ridges and cuspules in the trigonid basin (fig. 5 (3)). In view of these features, we cannot assert definitely the identity of this fossil with the living form, though it may well prove to fall within its range of variation. It may also be remarked that this tooth does not show close correspondence with any of the Canid fossils described by Broom from Sterkfontein and elsewhere.

Cf. *Lycaon pictus* (Burchell).

The posterior half of a lower right fourth premolar appears to be that of a large canid. It agrees well in size with that of the living Cape Hunting Dog, but differs slightly in the detail of the posterior cingulum cusp. In view of its broken condition, closer comparisons are impossible. A worn

lower incisor tooth agrees well in form with the left third incisor of *Lycaon*, but is a little larger than any specimen of this genus actually examined.

Order Artiodactyla.

Family Bovidae.

A moderately large number of antelope teeth is present in the Witwatersrand collection, but some of these are too fragmental to permit of possible identification. Incisor teeth and some milk teeth provide unprofitable material, and carpal and other bones, a skull fragment and small pieces of horn core are also incapable of reference. There remain, however, some forty teeth, part of a mandible and two partial horn cores which provide reasonable material for identification, and these may be briefly considered.

Peloroceras helmei (Lyle).

Two large upper second molars and a fragment are similar to those of the hartebees but very much larger. Lyle (1931) refers a comparable tooth

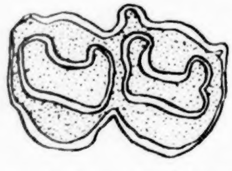

Fig. 6.—Occlusal aspect of upper left second molar referred to *Peloroceras helmei*.

to her species "*Bubalis*" *helmei* which was founded on horn cores, and for which van Hoepen (1932 *b*) erected the genus Peloroceras. Lower teeth have recently also been ascribed to this species (Cooke, 1940). One of the upper teeth from Vlakkraal is figured here (fig. 6).

Connochaetes cf. *taurinus* (Burchell).

Five upper molars and a premolar, two complete lower molars, three broken lower teeth and a lower premolar are very similar indeed to the corresponding teeth of the Blue Wildebeest. In view of the presence at Floris Bad of an extinct form *Connochaetes antiquus* Broom (1913) the possibility that these teeth might belong to that form cannot be dismissed, though they appear very close indeed to the living form.

Damaliscus cf. *albifrons* (Burchell).

Four upper molars, two lower molars, a broken lower tooth, and four premolars are similar both to those of the Blesbok and of the Sassaby.

They have been tentatively ascribed to the former type, as this is the one indigenous to the area.

Damaliscus cf. *pygargus* (Pallas).

A second damaliscine is apparently represented by two upper and two lower molars smaller than those of *D. albifrons* or *D. lunatus*. These compare closely with those of the Bontebok.

Antidorcas marsupialis (Zimmermann).

A well-worn upper tooth with a prominent narrow mesostyle is certainly that of a Springbok, and two complete and two broken lower molars also agree with this species. Two unerupted lower teeth appear also to belong here, and an upper premolar may also be referred.

Cf. *Sylvicapra grimmia* (Linnaeus).

A small part of a mandible bearing third and fourth premolars agrees in size and general character with the living Cape Duiker. An almost complete horn core also corresponds with this species, but the nature of the material does not permit of certain identification. We have, however, recognised undoubted teeth of this species in material from the Floris Bad site.

Cf. *Taurotragus oryx* (Pallas).

A small part of a horn core shows the typical spiral grooving of the Eland, but the fragment is small and no teeth of corresponding character have been found. This species is reported from Floris Bad both by Broom (1913) and by Lyle (1931), so that our identification is a probable one.

Antilope gen. et spec. indet.

Three very hypsodont lower teeth and a corresponding upper tooth cannot be placed into any known species. They agree in general pattern most closely with the Impala, but are transversely narrower. They also have certain characters in common with the Springbok and the Cape Duiker, but are too hypsodont and complex for the former and too large to be the latter. Similar teeth occur in the Floris Bad material available to us, and it would appear that the species was a common one. It seems probable that these teeth belong to an extinct species, but at present it would be unwise to state that this is the case. The teeth from Vlakkraal

are shown in fig. 7 in comparison with those of an Impala and a Cape Duiker.

FIG. 7.—Occlusal view of lower and upper molars of the unidentified antelope (centre) compared with corresponding teeth of the Impala (above) and the Cape Duiker (below).

Fam. HIPPOPOTAMIDAE; Gen. *Hippopotamus.*

Hippopotamus cf. *amphibius* Linn.

A fragment of a large tooth with very rugose enamel appears to be unquestionably part of the premolar of a Hippopotamus. It is curious that this should be the only relic of this type in our material, since in the majority of collections from the closely similar and partly contemporaneous deposits at Floris Bad Hippopotamus is abundantly represented.

Fam. SUIDAE; Gen. *Phacochoerus* Cuvier.

A number of supposed species of fossil wart-hogs have been described from South Africa, but until very recently the comparative basis for the establishment of these species has been uncertain and the position confused. Dreyer and Lyle (1931), recognising only one living species of Phacochoerus, described four new fossil species, two of which came from Floris Bad. In 1932, E. C. N. and H. E. van Hoepen, after a consideration of the features of some living skulls, distinguished two recent species and rejected Dreyer and Lyle's four species as synonyms of these. At the same time they erected a new species of Phacochoerus and two others falling into new and distinct, though allied, genera (Stylochoerus and Synaptochoerus); other genera and species erected by them at the same time belong to the Notochoerus type, with which we are not concerned in this study.

Shaw (1938) made a thorough and careful study of the growth changes and variations in the teeth of the living wart-hog *P. africanus.* He also reviewed the described fossil types, reducing Stylochoerus and Synaptochoerus to synonyms of Phacochoerus, and all the species to synonyms of the living *P. africanus* or the recently extinct *P. aethiopicus.* Regarding

these two species he confirmed the conclusions of the van Hoepens (1932), that the third molars are in most respects similar, but differ in the course of eruption and root formation. Roots develop upon the anterior columns of *P. africanus* before attrition of the posterior column has commenced, whereas in *P. aethiopicus* closure of roots only occurs considerably later, after all the columns have been abraded. It is thus possible to recognise among fossil forms teeth of the "*africanus* type" and of the "*aethiopicus* type."

Shaw concluded that the range of variation of the fossil material available to him was probably within that of the two recent species, and accordingly assigned the fossil forms to these two species. However, one of the present writers (H. B. S. C.) brought to the notice of Shaw a newly discovered fossil phacochoere tooth which was very much too large to fall into either of these species; this has been described (Shaw and Cooke, 1940) as a new species *P. altidens*. In the light of this discovery it appeared advisable to reconsider the status of the fossil species, and in this reconsideration Professor Shaw has kindly accorded the authors every assistance by placing his collections and notes at their disposal. We now consider that two additional species can be recognised, one of the *aethiopicus* type but larger than *P. aethiopicus* proper, the other of the *africanus* type but consistently larger than the normal *P. africanus* though lying on the extreme upper limit of variation of that species. Both these forms are represented in the Vlakkraal material, and are described below as *P. compactus* (van Hoepen and van Hoepen) and *P. helmei* Dreyer and Lyle.

Phacochoerus aethiopicus (Pallas).

P. venteri Dreyer and Lyle, 1931.
P. aethiopicus van Hoepen and van Hoepen, 1932.

The greater part of the wart-hog remains from Vlakkraal, comprising third molars in various stages of wear and also some anterior teeth, appears to belong to this species. Four complete third molars show no anterior root development despite the presence of well-worn posterior columns, and in size and other characters agree well with *P. aethiopicus* as now understood. Five third molars are incompletely erupted, and cannot therefore be certainly distinguished from *P. africanus*, nor can the four second molars, three broken third molars, a milk molar or a canine be certainly referred, but in view of the undoubted presence of *P. aethiopicus* there are no grounds for the separation of any of these specimens. The teeth belonging to the South African Museum have been labelled "*P. venteri*," presumably by Dreyer; they certainly correspond with the teeth described under that name by Dreyer and Lyle, except that the third molars somewhat exceed the dimensions of the type specimen. These authors were apparently under the

impression that all recent wart-hogs possess differentiated anterior roots to the third molar, and therefore naturally regarded this as a distinct species.

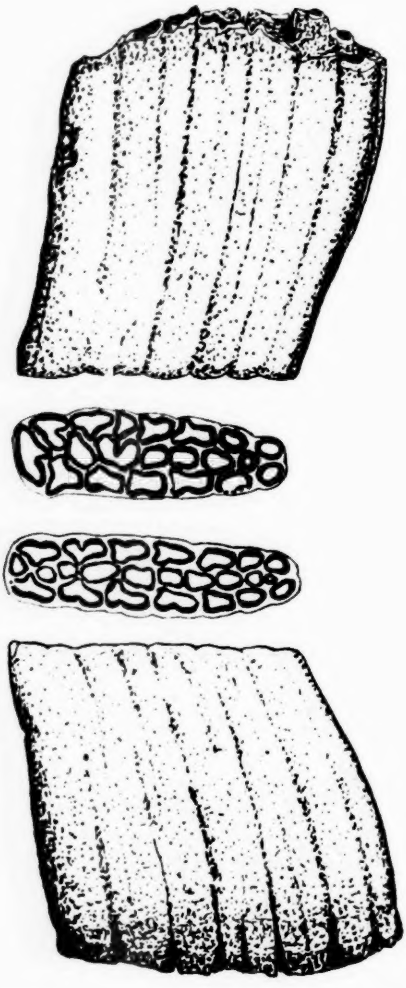

FIG. 8.—Lateral and occlusal aspects of upper and lower third molars of *Phacochoerus aethiopicus*.

The four complete third molars have the following dimensions:—

	Upper.		Lower.	
	S.A.M. 10939.	W.U. 896–4.B.	S.A.M. 10939.	W.U. 896–4.A.
Maximum height . .	58 mm.	48 mm. +	49 mm.	40 mm. +
Maximum length . .	49 ,,	47 ,,	54 ,,	49 ,,
Occlusal length . .	42 ,,	41 ,,	44 ,,	46 ,,
Occlusal breadth . .	13·5 ,,	13 ,,	13 ,,	12 ,,

Two of these teeth (those belonging to the South African Museum collection) are illustrated in fig. 8. From this it will be seen that these teeth display no significant variation from the normal structure of the "*aethiopicus* type" molar. The other complete teeth show no fundamental differences from those figured. It is, however, worthy of note that the upper molar W.U. 896–4.B presents two accessory median columns, which persist from the crown to the base of the tooth. The presence of these columns gives to this tooth a crown pattern almost identical with that of the type of *P. dreyeri* Dreyer and Lyle, which species it may be remarked is almost certainly a synonym of *P. aethiopicus* and not of *P. africanus* as suggested by the van Hoepens. None of the imperfect or incompletely erupted teeth assigned to *P. aethiopicus* display any unusual features; several of them, however, are appreciably narrower (9·5–11 mm.) than the complete teeth.

Phacochoerus compactus (van Hoepen and van Hoepen).

Stylochoerus compactus van Hoepen and van Hoepen, 1932.
Phacochoerus aethiopicus? Shaw, 1938.

Four third upper molar teeth in the collection resemble those of *P. aethiopicus* in possessing abraded posterior columns while lacking development of anterior roots. However, they so much exceed in size the typical molar of that species that it is difficult to assign them to it, though Shaw formerly regarded one of these teeth which belongs to the Witwatersrand collection as *P. aethiopicus*. The corresponding tooth for the opposite side of the same dentition, which is in the South African Museum collection, is labelled *P. helmei*, but with this reference we certainly cannot agree, since *P. helmei* belongs clearly to the *africanus* group (*vide infra*).

This pair of teeth has the dimensions:

	W.U. 896–4.C.	S.A.M. 10937.
Maximum height . .	62 mm.	62 mm.
Maximum length . .	59 ,,	57·5 ,,
Occlusal length . .	52·5 ,,	51 ,, +
Occlusal breadth . .	15·5 ,,	15·5 ,,

The former tooth is illustrated in fig. 9. On comparing this tooth with that assigned to *P. aethiopicus*, it will be seen to differ not only in size but in

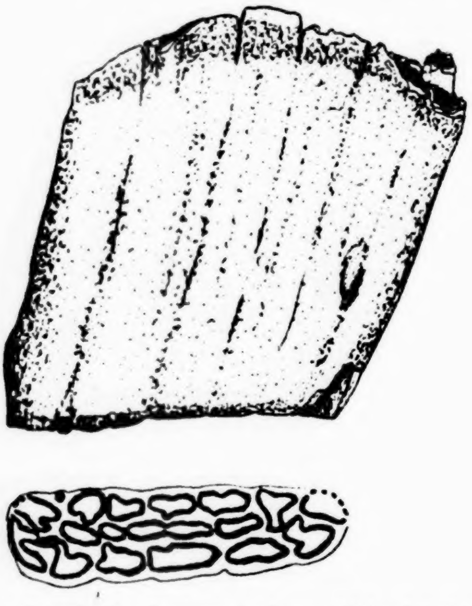

FIG. 9.—Lateral and occlusal aspects of upper third molar referred to *Phacochoerus compactus*.

many features of crown pattern. Chief among these are the greater elongation of the columns, especially the marginals, their more irregular outline and their tendency to become united into complex figures. A further manifestation of this complexity is the presence on this tooth of numerous small accessory conules ("paramolars") at various levels.

We have also assigned to this group two other teeth in the South African Museum collection (S.A.M. 10939) which bear the identification (presumably due to Dreyer) "*P. venteri* cf. Stylochoerus." One of these teeth is complete

except at the base; the other lacks its anterior extremity. Both, though somewhat smaller than the teeth just described, appreciably exceed the typical dimensions of *P. aethiopicus*, their measurements being:

Maximum height . .	52 mm. +	56 mm. +	
Maximum length . .	54 ,,	49 ,,	+ (? 56 mm.)
Occlusal length . .	50 ,,	45 ,,	+ (? 52 mm.)
Occlusal breadth . .	15·5 ,,	16 ,,	

The more complete tooth displays the same elongated and complex columns as are seen in the previous specimens. Indeed, the complication is even more pronounced, in that several of the marginals are so deeply indented that a portion is almost constricted off, suggesting a tendency to the formation of accessory median columns. In the less perfect teeth, while some of the columns are of the elongated type, others are smaller and simpler; they are also more numerous. This tooth is, however, distinguished by the presence in its posterior portion of two regular rows of median columns.

Shaw has advanced what appears to be entirely adequate evidence that the characters upon which the genus Stylochoerus was established by the van Hoepens are not truly of differential value, since they are found sporadically in the recent species. The type tooth of the species *compactus*, however, is considerably larger than the corresponding normal recent tooth, and appears to lie outside the reasonable range of variation of *P. aethiopicus*. It is considered, therefore, that *compactus* may with good reason be regarded as a valid species of the genus Phacochoerus, related to *P. aethiopicus* by its lack of early differentiated roots, but distinguished by its greater size and a tendency towards the development of a more complex enamel pattern. Shaw has shown that the presence of more than three rows of columns is an occasional feature of the living forms, and is therefore not of specific importance. However, in teeth as large as those of *P. compactus* the development of an extra row of columns may well be a more common feature, while small accessory conules on the side of the teeth in our collection indicate the same tendency. In both its size and its enamel characters, *P. compactus* lies largely in an intermediate position between *P. aethiopicus* and the gigantic *P. altidens* Shaw and Cooke.

The teeth from Vlakkraal just described are admittedly not quite so high as the type of *P. compactus*, but as it is not possible to estimate the degree of abrasion, the height has no precise value. These teeth otherwise agree closely with *P. compactus* in those features in which they differ from the normal *P. aethiopicus*, and we have therefore felt justified in assigning them to the former rather than to the latter species.

Phacochoerus helmei Dreyer and Lyle.

P. helmei Dreyer and Lyle, 1931.
P. africanus van Hoepen and van Hoepen, 1932.
[*P. laticolumnatus* van Hoepen and van Hoepen, 1932.]
P. aethiopicus Shaw, 1938.

Four third molar teeth from Vlakkraal have well-developed anterior roots and apparently belong to the *africanus* type. These agree very closely with the teeth described by Dreyer and Lyle as *P. helmei*, which these authors distinguished by various characters from the recent form called by them "*P. aethiopicus*," in reality *P. africanus* according to the definition adopted by the van Hoepens and by Shaw. The distinctness of this species was not upheld by the van Hoepens, who concluded that *P. helmei* is a synonym of *P. africanus*. Shaw, who examined two lower molars of this group in the Witwatersrand collection, observed that they differed appreciably from those of *P. africanus*, and merged them with other material from this site in *P. aethiopicus*. This conclusion is difficult to accept, for the anterior roots are too well developed in relation to the abrasion of the posterior columns for them to be placed in the *aethiopicus* group. The closure of the roots, however, seems to have occurred a little later than is generally the case in the living *P. africanus*. They therefore appear certainly to be specifically distinct from *P. aethiopicus*, but at the same time seem more specialised and also larger than the typical *P. africanus*. The average length of the occlusal surface in correspondingly worn third molars of *P. africanus* is about 50 mm.; in the type specimens of *P. helmei* it is 63·5 mm. in the upper and 61 mm. in the lower tooth; our specimens measure 68·5, 67·5, 68·0, and 56·5 mm. respectively. It cannot be said that these dimensions lie outside the possible limits for *P. africanus*, for exceptional teeth in living skulls may be almost as long. However, such large teeth are most rare in the living form, and the existence in the fossil state of at least six or seven teeth of such consistently large dimensions, coupled with their other characters, makes their distinction probable.

Three of the four teeth from Vlakkraal assigned to this type belong to one dentition, an upper and a lower molar in occlusion (fig. 10) forming part of the South African Museum collection, while the lower molar of the opposite side is in the Witwatersrand collection. These teeth show a degree of root development comparable with Shaw's stage F in *P. africanus*; the abrasion of the crown has, however, progressed further, approximating to Shaw's stage G. The same discrepancy is apparent in the remaining tooth in the Witwatersrand collection, which is in a less abraded condition, corresponding in root development to stage E, but in crown pattern to

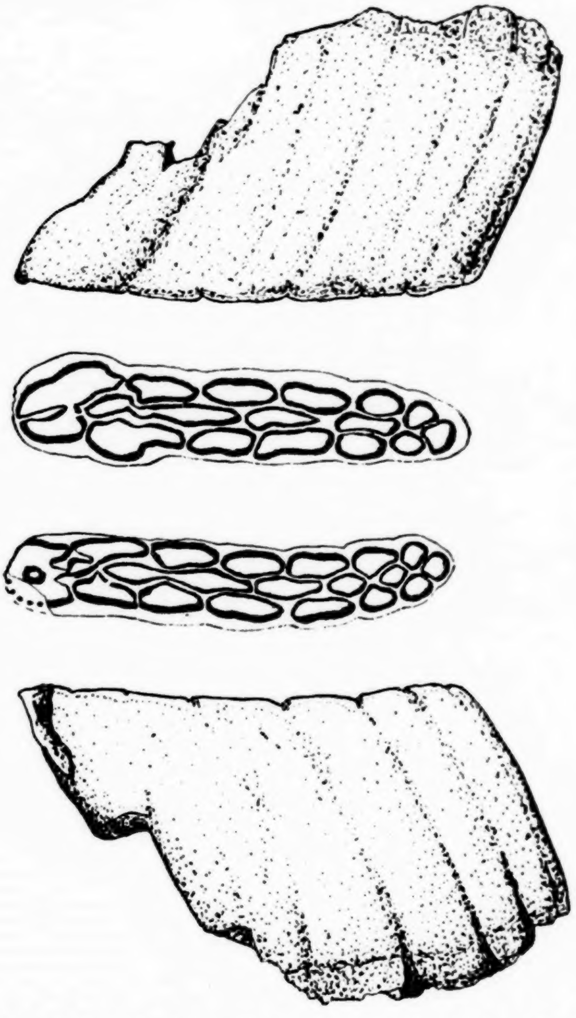

FIG. 10.—Lateral and occlusal views of upper and lower third molars of *Phacochoerus helmei.*

stage **F**. This discrepancy appears to result from the delay in root formation in *P. helmei* as compared with *P. africanus.*

The dimensions of these teeth are:

	Upper.		Lower.	
	S.A.M. 10937.	S.A.M. 10937.	W.U. 896–5 B.	W.U. 896–5 A.
Maximum height . .	44·0 mm.	47·0 mm.	46·0 mm.	52·0 mm.
Maximum length . .	69·0 ,,	69·0 ,,	69·0 ,,	61·0 ,,
Occlusal length . .	68·5 ,,	67·5 ,,	68·0 ,,	56·5 ,,
Occlusal breadth . .	16·0 ,,	13·5 ,,	13·5 ,,	13·5 ,,

In all these specimens the most conspicuous difference in crown pattern for the *P. africanus* tooth at the same stage of wear is the elongation of many of the columns, particularly the marginals. The more abraded teeth show extensive fusion of columns in their anterior portion, most extensive in the median row. There are fewer minor irregularities of the enamel pattern than in the teeth assigned to *P. compactus*; however, the least abraded tooth displays two small accessory columns in its posterior portion, one of which appears to persist.

We therefore regard *P. helmei* as a valid species, with third molars consistently larger than the normal *P. africanus* and differing also in the somewhat later development of roots and possibly in the elongation and flattening of the marginal columns to a greater degree than is usual in the living species. These characters are also found in the species described by van Hoepen and van Hoepen as *P. laticolumnatus*, and it is probable that this may be a synonym of *P. helmei* rather than of the recent species as suggested by Shaw. *P. helmei*, in fact, bears to *P. africanus* much the same relationship as *P. compactus* does to *P. aethiopicus*. It may be remarked that typical *P. africanus* molars are not known to us in a recent or subfossil state from the Orange Free State.

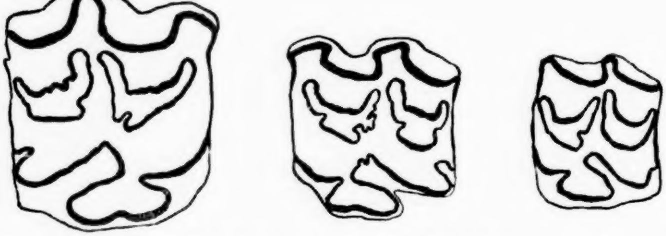

Fig. 11.—Occlusal views of well-worn upper molars of the three species of horse from Vlakkraal to illustrate the differences in size and enamel pattern.

Order PERISSODACTYLA.

Family EQUIDAE; Genus *Equus* Linnaeus.

The equine remains from this site number in all forty-four teeth, including some milk teeth and incisors. All are petrified in the typical manner. The cheek teeth fall clearly into three size groups, and the enamel and other characters within each group support entirely the rough division on a size basis. A well-worn upper tooth of each group is shown in fig. 11.

Equus burchellii (Gray).

Equus lylei Dreyer, 1931 (in Dreyer and Lyle, 1931).
E. quagga wahlbergi Haughton, 1932.

The teeth of the smallest size group constitute the greater part of the equine remains and form a homogeneous assemblage, including an incisor, milk teeth, and upper and lower permanent teeth. The Witwatersrand collection contains a milk and a permanent incisor, two upper and two lower milk molars, two unworn and six abraded upper cheek teeth, and five lower cheek teeth. The South African Museum material includes a series of upper cheek teeth from P_4 to M_3 in an early stage of wear, and a composite lower series from P_2 to M_3, some of the teeth being also relatively little worn. The two South African Museum "series" are labelled *E. lylei*, possibly by Dreyer, and they agree both in size and enamel pattern with the teeth described by Dreyer from Floris Bad under that name. Taking the cheek teeth as a whole, the uppers average 22 mm. and the lowers 13·5 mm. in transverse diameter, and both in size and in enamel pattern they fall within the range of variation of the living Burchell's Zebra. They are indeed almost completely identical with the teeth of one of the skulls in the Transvaal Museum. Haughton (1932) has alreay referred *E. lylei* as a probable synonym of what he called "*Equus quagga wahlbergi*," *i.e.* a member of the Burchell group, and this reference now appears to be established. There is good reason as a result of recent (as yet unpublished) work by one of the authors, however, to regard Burchell's Zebra as very distinct indeed from the recently exterminated true Quagga, and the living form merits the full specific designation *E. burchellii*.

Equus cf. *kuhni* Broom.

Four upper teeth—an unworn second molar, a broken third molar, and two much abraded molars—have a transverse breadth greater than is found in the living species. The two very worn teeth are now 28·5 mm. and 29 mm. broad across the enamel, and the unabraded second molar has a

breadth of 28·5 mm. an inch below the crown. Despite the simplification of the crown pattern consequent upon wear, a deep pli protoconule is still present and pre- and post-fossette folds are also developed, from which it may be inferred that the pattern in earlier wear must have been quite complex. The unworn molar is, unfortunately, too brittle to section satisfactorily, so that the early pattern can only be indirectly inferred. Though narrower by a millimetre they agree essentially with the type of *Equus kuhni* and even more closely with teeth from a cave near Kuruman which were recently referred to that species (Cooke, 1940). The condition of the teeth, however, prevents certain diagnosis.

Equus capensis Broom.

Equus helmei Dreyer, 1931.
E. cawoodi Haughton, 1932.

In the Vlakkraal material from the South African Museum there is an excellent lower left dentition, comprising P_2–M_2 in normal wear, and an odd third molar which has been used to complete the series but which does not appear to belong to the actual dentition. In the Witwatersrand collection there occurs a lower right P_3 in the same state of wear which agrees very closely with the corresponding tooth in the series and which almost certainly belongs to the opposite side of the same individual. These lower teeth range in transverse diameter (excluding M_3) from 18 to 19·5 mm. and agree in size and in pattern very closely indeed with the type series and neotype of *E. capensis* Broom. They are illustrated in fig. 12, and provide the best preserved and most valuable material of this large extinct species so far known.

Three very worn upper cheek teeth in the Witwatersrand collection measure respectively 32·5 mm., 30·5 mm., and 35 mm. in breadth across the enamel. These teeth are therefore almost certainly the upper teeth of *E. capensis*, and support the association recently described at Wonderwerk Cave, near Kuruman (Cooke, 1940). As in that case, the pattern of the upper teeth agrees essentially with that of *E. cawoodi* Broom, and confirms the fact that *E. cawoodi* is a synonym of *E. capensis*. These three teeth also agree with the teeth described by Dreyer as *E. helmei*, though the protocone in one is longer than in Dreyer's species and more like the type tooth of *E. cawoodi*. Haughton (1932) placed *E. helmei* as a synonym of *E. cawoodi*, so that the identity of this latter species and *E. capensis* now seems certain.

In the Witwatersrand collection there is also a large upper left second incisor which may belong to this species.

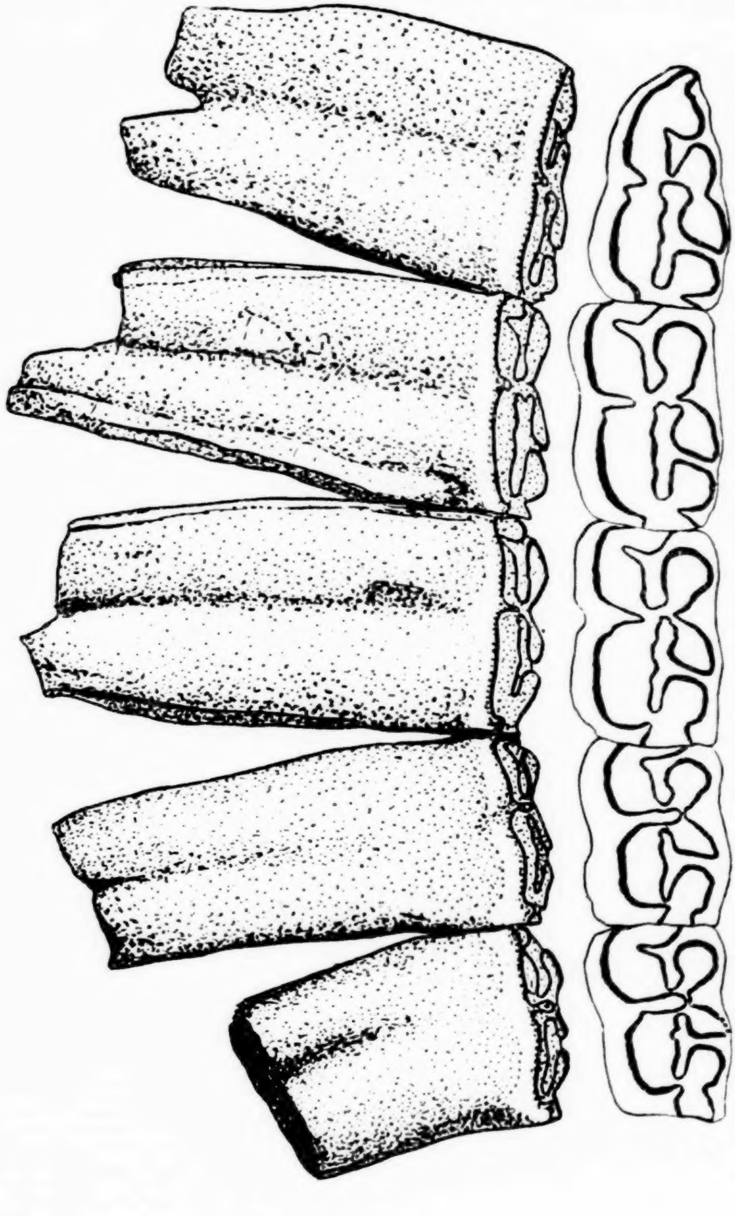

FIG. 12.—Outer lateral view and enamel pattern of the occlusal surfaces of lower left dentition of *Equus capensis*.

Discussion.

The Vlakkraal fauna as represented by these collections thus comprise seven or eight types of antelope, apparently three types of wart-hog and three of horse, the hippopotamus, three carnivores and a rodent, as well as the ostrich and at least one fish. We know also that a large buffalo, presumably "*Bubalus*" *bainii* Seeley, has been found in the deposit, although it is not represented in our material, and it is not impossible that other forms may be present in the collection at Bloemfontein. Altogether the list is an imposing one, and can be equalled from few other single sites except Floris Bad.

The fauna of Floris Bad has been described by Broom (1913) and by Dreyer and Lyle (1931). Certain revisions of the determinations of the latter authors have been effected by Haughton (1932), E. C. N. and H. E. van Hoepen (1932), and E. C. N. van Hoepen (1932 *b*). In the course of the description of the Vlakkraal fauna opinions have been expressed concerning a number of these debated points. There remain several differences between the Floris Bad and Vlakkraal faunal lists as these are recorded up to the present time; a number of forms reported from Floris Bad are not represented in our material from Vlakkraal, which, however, includes certain types not listed in the publications dealing with Floris Bad.

It may be remarked that among the collections loaned to us by the South African Museum there is a large assemblage of teeth, principally of bovids, stated to come from the Hagenstad Salt Pan, *i.e.* presumably from Floris Bad. In this material we have found only two species not represented at Vlakkraal. All the Vlakkraal antelopes are present, including the unnamed form, and in addition there is a form apparently allied to Kobus (possibly "*Kobus*" *venterae* Broom). There is also present in this Hagenstad collection a milk molar of the Black Rhinoceros (*Diceros bicornis*) which is worthy of record since no Rhinoceros has been recorded in the Floris Bad fauna either by Broom or by Dreyer and Lyle.

There are still many dubious points concerning the Floris Bad fauna, and the advances in our knowledge since the original studies make desirable at some future time a re-examination of the material from that site. It would appear, however, that there is a close similarity between the faunas of Vlakkraal and Floris Bad.

In this connection it must be remembered that the complex deposits of the Floris Bad site appear to contain a sequence of cultures, with which the faunal elements are very imperfectly correlated. At Vlakkraal, the industry has been shown by Mr. Malan's analysis to be almost completely homogeneous, representing a single cultural phase, the Mazelspoort Culture, an advanced, though not necessarily the final, expression of the Middle Stone

Age. This culture is represented also at Floris Bad, where there are grounds for attributing it to the later part of the history of the site.

The fossil material from Vlakkraal is very consistent in its physical state, and we are led to infer that it constitutes a unit contemporary with the associated industry. Bearing in mind the possibility of missing faunal elements in the collection from Vlakkraal, it may be suggested that any extinct types from Floris Bad which are *not* represented at Vlakkraal may belong to the earlier cultural phases of the latter site. So close are the parallels between the two sites, however, that both may be regarded as representing the fauna of the Middle Stone Age. Until the Floris Bad material has been more fully interpreted, the Vlakkraal fauna must be taken as that particularly associated with the Mazelspoort cultural phase. The only form previously associated with this culture is "*Bubalus*" *bainii* (regarded by van Hoepen as identical with the North African *B. antiquus*), which has been recorded from the type site (van Hoepen, 1932 *a*).

This fauna, though it includes a number of extinct forms, has essentially the aspect of that of the modern high-veld. From this it may be inferred that the physical conditions prevailing in the area when this fauna flourished were not greatly different from those of the present day. The proportion of undoubtedly extinct types is a noteworthy feature. *Equus capensis* "*Bubalus*" *bainii*, and *Peloroceras helmei* are not only extinct, but are in many ways remote from the surviving types; *Phacochoerus compactus*, *P. helmei*, and the horse described as *Equus* cf. *kuhni*, though more closely related to living forms, are also extinct. Of the remaining types the small unnamed antelope does not now appear to exist, and in many other cases there seem to be differences between the fossil and the living forms. Thus out of a total of twenty-two species, one-third appear certainly to be extinct; even if the remaining forms are identical with living types, this proportion of extinct forms is a high one.

It has been observed more than once that Middle Stone Age industries may be associated with certain extinct species, notably *Equus capensis* and "*Bubalus*" *bainii*, and that these forms have not been recorded in certain association with Later Stone Age remains. Moreover, there is evidence of a distinct climatic break which appears to coincide with (and possibly to determine) the end of the Middle Stone Age. Since we have excellent evidence that many now extinct animal forms lived during late Middle Stone Age times, while no extinct forms have so far been found with the Later Stone Age, we may suspect that the increasing aridity at the end of the Middle Stone Age was responsible for the extinction itself. On these grounds it appears reasonable to regard this climatic break at the end of the Middle Stone Age as marking the end of the Pleistocene in southern Africa. If this be accepted, the Mazelspoort Culture and the fauna associated with

it are to be regarded as late Upper Pleistocene. The Later Stone Age with its impoverished fauna would accordingly be regarded as falling within the Holocene.

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EXPLANATION OF FIGURES.

(All natural size unless otherwise specified.)

FIG. 1.—(1) Convergent longitudinal point on Levallois flake, with faceted striking platform, showing no secondary trimming. (2) Convergent longitudinal point on Levallois flake with faceted striking platform: carefully trimmed on upper face. Prepared striking platform trimmed to form a butt end-scraper. (3) Trimmed point on Levallois flake with prepared striking platform trimmed to form a butt end-scraper.

FIG. 2.—(1) Trimmed point on Levallois flake, with reduced bulb of percussion. (2) High-keeled trimmed point on Levallois flake. (3) High-keeled trimmed point on Levallois flake with reduced bulb of percussion. (4) Side-scraper on Levallois flake, secondary work on flake surface only.

FIG. 3.—Two views and three sections of bifaced point of "lancehead" type.

FIG. 4.—(1) Point on Levallois flake showing secondary work on flake surface. (2) "Duckbill" end-scraper. (3) Serrated scraper on Levallois flake. (4) Side-scraper on Levallois flake.

SOME NOTES ON THE EFFECTS OF THE INCIDENCE OF RAIN ON THE DISTRIBUTION OF RAINFALL OVER THE SURFACE OF UNLEVEL GROUND.

By H. G. Fourcade.

(With six Text-figures.)

(Read June 18, 1941.)

I. Precipitation on Slopes.

Consider a rain-gauge set at an inclination a towards the direction from which rain is falling at an inclination i to the vertical. Let R be the rainfall recorded by a gauge horizontally set. In fig. 1, BC is the

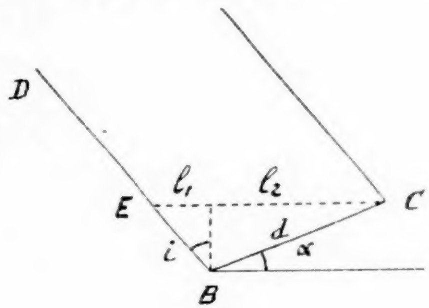

Fig. 1.

gauge, of diameter d, and BD the direction of the rain. The catch C of the gauge will be equal to the rainfall over an ellipse with horizontal axes CE and d. We have

$$l_1 = d \cos a,$$
$$l_2 = d \sin a \tan i.$$

The area of the ellipse will then be

$$A = \frac{\pi}{4} d(l_1 + l_2)$$

$$= \frac{\pi}{4} d^2 (\cos a + \sin a \tan i).$$

The horizontal area of the gauge is

$$\frac{\pi}{4} d^2 \cos a,$$

so that the rainfall received by the gauge per unit of its horizontal area is

$$r = R + R \tan a \tan i = \frac{C}{a \cos a},$$

where a is the actual area of the gauge.

When the direction ϖ from which rain is falling is at an angle $(\beta - \varpi)$ from the aspect β of the slope of the gauge,

$$r = R + R \tan a \tan i \cos (\beta - \varpi).$$

$$\text{If} \quad (\beta - \varpi) = 90^\circ, \qquad \cos (\beta - \varpi) = 0,$$

that is, the catch on a slope of aspect at right angles to the direction of the rain is independent of the inclination of the rain.

The influence of the inclination of rain on the rainfall over a slope has been noted before, as by Horton (1) in 1919, and already by the present writer as far back as 1889 (2), but its implications do not appear to have been followed up in sufficient detail.

Set up a composite gauge with four vertical apertures facing N., E., S., and W., and one horizontal aperture. Let a be the area of each vertical aperture, i_n and i_e the N. and E. components of the inclination i of the rain, and ϖ, reckoned from N. by E., the direction in azimuth from which rain is falling. The rainfall R is given by the horizontal gauge. We have

$$\tan i_e = \frac{R_e}{R}, \qquad \tan i_n = \frac{R_n}{R},$$

$$\tan \varpi = \frac{R_e}{R_n} = \frac{\tan i_e}{\tan i_n},$$

$$\tan i = \frac{R_n}{R \cos \varpi} = \frac{R_e}{R \sin \varpi}$$

$$= \frac{\tan i_n}{\cos \varpi} = \frac{\tan i_e}{\sin \varpi}.$$

When i_n and i_e are both positive the catches in the N. and E. vertical gauges of area a will be

$$C_n = Ra \tan i_n \quad \text{and} \quad C_e = Ra \tan i_e.$$

Substituting C_n/Ra and C_e/Ra for $\tan i_n$ and $\tan i_e$,

$$r = R + \frac{\tan a}{a} (\cos \beta C_n + \sin \beta C_e).$$

For another period in which the rainfall is R' and the vertical catches C_n' and C_e',

$$r' = R' + \frac{\tan a}{a}(\cos \beta C_n' + \sin \beta C_e').$$

Adding

$$r + r' = R + R' + \frac{\tan a}{a}[\cos \beta(C_n + C_n') + \sin \beta(C_e + C_e')].$$

The result is therefore the same whether we deduce the total equivalent rainfall from the sum of equivalent falls computed separately, or directly, from the aggregate catches of each gauge. The partial catches of the vertical gauges are therefore strictly additive for each, irrespective of the directions or inclinations of the intermediate rains.*

When C_n' and C_e' are negative they become C_s and C_w. Finally, then, the equivalent rainfall on a slope is given by

$$r = R + \frac{\tan a}{a}[\cos \beta(C_n - C_s) + \sin \beta(C_e - C_w)],$$

with

$$\tan i_n = \frac{C_n - C_s}{Ra}, \qquad \tan i_e = \frac{C_e - C_w}{Ra}.$$

Example.

Over a period with a precipitation of 19·70 in. there is collected in vertical gauges of 10 sq. in. area

$$\begin{aligned} C_n &= 0{\cdot}67 \text{ c. in.} \\ C_e &= 4{\cdot}50 \quad ,, \\ C_s &= 14{\cdot}00 \quad ,, \\ C_w &= 80{\cdot}00 \quad ,, \end{aligned}$$

$$\tan i_n = \frac{0{\cdot}67 - 14{\cdot}00}{197} = -0{\cdot}0677, \qquad i_n = -3^\circ\ 50',$$

$$\tan i_e = \frac{4{\cdot}50 - 80{\cdot}00}{197} = -0{\cdot}383, \qquad i_e = -21^\circ\ 0',$$

$$\tan \varpi = \frac{-0{\cdot}383}{-0{\cdot}0677} = 5{\cdot}67, \qquad \varpi = 260^\circ\ 0',$$

$$\left.\begin{aligned} \tan i &= \frac{-0{\cdot}383}{-0{\cdot}985} = 0{\cdot}389 \\ &= \frac{-0{\cdot}0677}{-0{\cdot}1736} = 0{\cdot}390 \end{aligned}\right\} \qquad i = 21^\circ\ 20'.$$

* This result follows at once from the rule for the addition of vectors.

The equivalent rainfall on slopes of N. and S. aspects, and inclination a, would then be

$$19{\cdot}7 \mp 1{\cdot}33 \tan a.$$

On slopes of E. and W. aspects,

$$19{\cdot}7 \mp 7{\cdot}50 \tan a;$$

or, for particular values of a, and more aspects,

$a=$	10°	20°	30°	40°
N.	19·5	19·4	18·9	18·6
N.E.	18·6	17·4	16·1	14·4
E.	18·4	17·0	15·4	13·4
S.E.	18·9	18·1	17·2	16·0
S.	19·9	20·1	20·5	20·8
S.W.	20·8	22·0	23·3	25·0
W.	21·0	21·4	24·0	26·0
N.W.	20·5	21·3	22·2	23·4

Another method of determining the inclination and direction of rain consists of the use of four inclined gauges set to face the cardinal points.

For the two opposite gauges, each of area a, of a pair we have catches

$$C_1 = Ra\,(\cos a + \sin a \tan i_1),$$
$$C_2 = Ra\,(\cos a - \sin a \tan i_1),$$

whence

$$C_0 = Ra\frac{C_1 + C_2}{2 \cos a},$$

$$\tan i_1 = \frac{C_1 - C_2}{C_1 + C_2} \cot a = \frac{C_1 - C_2}{2C_0 \cos a}.$$

Two values i_e and i_n are obtained from the complementary pairs E.W. and N.S. Then, as before,

$$\tan \varpi = \frac{\tan i_e}{\tan i_n} \quad \text{and} \quad \tan i = \frac{\tan i_n}{\cos \varpi} = \frac{\tan i_e}{\sin \varpi}.$$

Separate catches for rains of different inclinations still become additive. For the equivalent vertical rainfalls r_1 and r_2 on any one gauge of the four, for catches C_1 and C_2, are

$$r_1 = R_1 + R_1 \tan a \tan i_1 = \frac{C_1}{a \cos a},$$

$$r_2 = R_2 + R_2 \tan a \tan i_2 = \frac{C_2}{a \cos a},$$

and

$$r_1 + r_2 = \frac{C_1 + C_2}{a \cos a}.$$

When the inclination of rain exceeds $\frac{\pi}{2} - a$, C_2 becomes negative and is not recorded by its gauge, so that a should be made small. But the efficiency decreasing as $\sin a$, a cannot be made very small. If the British rule, which applies to ordinary sites, that no obstruction must subtend a height of more than half its distance from the gauge, is observed, the maximum permissible slope of each of the gauge components will be 1 in 2, or $a = 26^\circ\ 30'$ for which $\sin a = 0{\cdot}45$, and max. $i = 63^\circ\ 30'$. For such a gauge

$i = 5^\circ$	$C_1/C_2 = 1{\cdot}09$
10	1·19
15	1·31
20	1·41

It may be preferable to tabulate, instead of the direction and inclination of rainfall, its horizontal N.S. and E.W. components. The advantage is that the data become directly additive or separable. R_n and R_e are given at once by the gauge with vertical aperture. For the other gauge with four inclined elements we have

$$R = \frac{C_n + C_s}{A} = \frac{C_e + C_w}{A},$$

$$R_n = \frac{C_n - C_s}{B}, \qquad R_e = \frac{C_e - C_w}{B},$$

$$\tan \varpi = \frac{R_e}{R_n},$$

$$\tan i = \frac{R_n}{R \cos \varpi} = \frac{R_e}{R \sin \varpi},$$

in which $A = 2a \cos a$ and $B = 2a \sin a$, both constants for the gauge.

II. Construction and Use of Gauges.

Fig. 2 is a diagram of a suitable composite gauge of the first type. Four vertical apertures, which may be 10 sq. in. in area, set to face N., E., S., and W., are connected in pairs, by widening receivers, to a central square chamber. Inclined baffles in the back half of each receiver serve to collect the rain that has not been deposited in the front half. The velocity of the air passing over the baffles being reduced to a fraction of that of the wind, practically every particle of even misty rain can be caught by spacing the baffles closely enough. The apertures are made of elongated shape, and their ends pointed, in order to reduce turbulence when the air stream crosses a pair of them at a small incidence.

The vertical rainfall could be measured by a horizontal gauge incorporated into the middle of the composite one, but it will probably be more convenient to measure it separately in a standard gauge placed alongside.

Standard gauges should, as a rule, be shielded. A long series of measurements during nineteen months on Mt. Washington (6284 ft.) by S. Pagliuca (3)

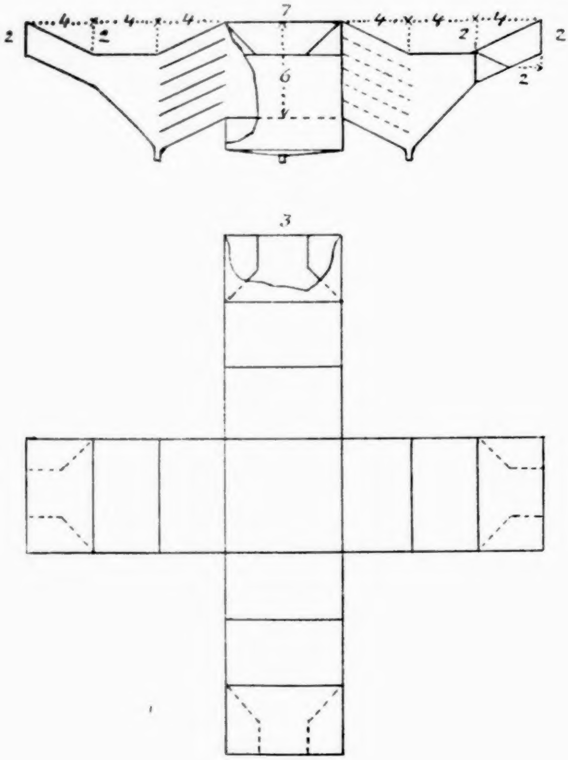

Fig. 2.

showed that with wind velocities up to 30 mi./h. shielded gauges collected 4 per cent. more than unshielded ones. With wind velocities between 30 and 75 mi./h. the increase was 40 per cent., and, above 75 mi./h., 42 per cent. It seems that 30 mi./h. is a critical velocity above which turbulence of a different character sets in. Other observers have found larger increases in moderate winds, but it may be that they took average velocities made up partly of exceptional gusts accompanied by the heaviest showers.

A wooden shield in the shape of an inverted truncated pyramid of 30×30 in. base, and sides at $45°$, was found by Pagliuca (3) to be a simple and efficient substitute for a Nipher shield.

A shielded gauge is nothing but a pit gauge raised above the surface of the ground, with the advantage that it is less affected by turbulence from the roughness of the ground, unless the pit gauge is surrounded by a smoothed space and provision made against splashing.

The second type of composite gauge that has been considered, the inclined composite, could consist of four funnels fixed on the faces, sloping 1 in 2, of the square pyramidal roof of a supporting box containing the receiving vessels. The further design will present no difficulty.

Another class of gauge, for use on mountain-slopes, are single inclined gauges set with their rim parallel to the surface of the ground; the catch of each divided by its area and by the cosine of its inclination gives the true equivalent rainfall over the slope.

III. Determination of Rainfall over a Catchment Area.

The practice of engineers is to estimate the volume of water falling as rain over a catchment area as being equal to the product of the area with the annual rainfall measured in standard horizontal gauges. (See, *e.g.*, Dict. Appl. Phys., vol. i (1932), p. 495.) To show that this rule can be very inaccurate, take (fig. 3) a section, in the direction of the rain, across a catchment area, from watershed A to watershed C. The arrows indicate the direction and force of the wind; the curved dotted lines the trajectories of raindrops.

Between A and B, at one height, the catch C_1 will be equal to the area of the strip $AB = l_1$ multiplied by the mean rainfall over the strip, as recorded by ordinary horizontal gauges, or $C_1 = l_1R_1$, independently of any varying inclination of the rain between A and B. From B to C the catch C_2 will be $l_2R_2(1 + \tan a \tan i)$, and the true total catch $C_1 + C_2$, not $l_1R_1 + l_2R_2$ but $l_1R_1 + l_2R_2(1 + \tan a \tan i)$.

The low velocity of fall of raindrops at high elevations, due to their smaller diameter, combines with the higher velocity of the wind to produce an average inclination of rain over BC always much higher than over AB, so that the difference between the true and the nominal catches may be considerable. To take a numerical example, supposing $l_1 = 3l_2$, $a = 30°$, $i = 75°$, and $R_2 = 2R_1$, which seem possible figures at the mountain end of a catchment, we get relative values, for the total catch, of 100 and 186, that is a true value 86 per cent. in excess of the nominal.

The difference between the true and the nominal rainfall has been called by Horton ((1), p. 359) the "roof effect." This roof effect, resulting from boundary conditions, will be more marked in a small catchment than

in a large one, and when comparing fluctuations of run-off with those of rainfall it may possibly be disregarded, as it is by engineers, without introducing serious error in the character of the relation. But it is otherwise when attempting a more complete study of the various gains and losses of water of a catchment, it becoming then essential to determine as accurately as possible the quantity of water received that has to be accounted for in the form of a balance-sheet of the rainfall.*

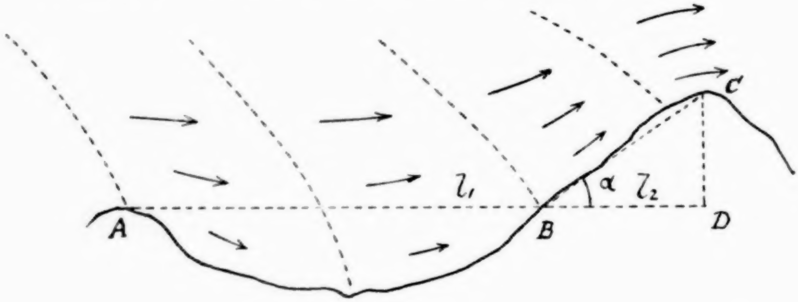

Fig. 3.

The rainfall over a catchment can be ascertained by subdividing the area into a number of topographical elements on each of which a gauge is set up, parallel to the equivalent slope of the element, and its catch divided by the cosine of its inclination. Or the fall on any of the elements may be derived from the catch of horizontal gauges corrected, from the indications of a composite gauge, by means of the formula

$$r = R + R \tan a \tan i \cos (\beta - \varpi).$$

The use of the second method should be restricted to the lower portion of a catchment, below a definite contour line, usually the greater portion, over which the wind would blow more uniformly than over the upper portion, but it may be extended to the whole of the catchment when there are no great differences in elevation. The composite gauge should be erected near the centre of the area on the most level ground available, preferably a rounded hilltop. The upper remaining extent may then be divided into sections comprising a middle ridge on which is located a gauge set parallel to the equivalent slope of the section. As the catch of the gauges will vary with altitude, two or three at different heights should

* The surface run-off, sub-surface run-off, evaporation, interception by plants and transpiration by plants, must in their sum equal the rainfall $\pm$ the loss or gain, during the period, of the stock of water stored in the catchment (in soil, rock, streams, lakes, marshes, dams, tanks).

be set up in one of the sections, all of them at one inclination, parallel to the equivalent slope of the whole of the section, from the indications of which the corrections needed to convert the catch of each gauge in the other sections into the average catch for its section may be estimated.

Inclined gauges for mountains on which the precipitation is high must necessarily be of small dimensions in order to keep down the quantity of water that has to be collected, particularly when the gauge cannot be visited and emptied daily.* Appropriately, they may consist of a cylindrical can of 10 sq. in. aperture with sides 6 in. high draining by means of a flexible tube into a 4-gallon drum placed lower down on the slope. The base of the gauge should be at ground level, and the surrounding surface cleared and smoothed.

The equivalent net slope of an area may be obtained by a method due to Horton (4). A graticule of N.S. and E.W. lines is laid upon a contoured map of the figure the slope of which is to be determined. The sum of the differences in elevation of the N.S. lines, at their intersections with the boundary, divided by the sum of the horizontal lengths of the lines, will give the N.S. component of the slope. The E.W. component is obtained similarly.

If (fig. 4) $\tan \alpha_n$ and $\tan \alpha_e$ are the N.S. and E.W. slope components, and OC is taken as 1,

$$h = \tan \alpha_n,$$

$$h/OA = \tan \alpha_e.$$

The line of dip BD of the plane BAC, and OD, are both perpendicular to the horizontal line AC. Whence

$$OD = \cos \beta = OA \sin \beta,$$

$$\tan \beta = \tan \alpha_e / \tan \alpha_n,$$

$$\tan \alpha = \frac{h}{OD} = \frac{\tan \alpha_n}{\cos \beta} = \frac{\tan \alpha_e}{\sin \beta}.$$

Horton (4) gets the equivalent formula

$$\tan \alpha = \sqrt{\tan^2 \alpha_n + \tan^2 \alpha_e}.$$

In the expression for the slope components the limiting values of $\Sigma(s\Delta d)$, when the graticule interval Δd becomes infinitely small, is the

* The importance of the size and accuracy of the collecting aperture of a gauge is sometimes unduly stressed having regard to the many greater sources of error in rainfall measurement, such as the variability of the fall over different points of even a small area. According to Ryves (5), "Trials with gauges of various diameters from 1 in. to 2 ft. have shown that if they are set perfectly level, and observed with great care, exactly the same rainfall has been recorded by all of them."

map area of the surface—that is, its horizontal projection P_z. Similarly $\Sigma(h_n\Delta d)=P_n$, and $\Sigma(h_e\Delta d)=P_e$, become the projections of the surface on the planes ZOE and ZON, so that $\tan\alpha_n=P_n/P_z$ and $\tan\alpha_e=P_e/P_z$. P_n and P_e are best obtained by plotting as ordinates the height differences of each N.S. and E.W. line, respectively, against abscissae s at Δd intervals and measuring the areas with a planimeter. If, through re-entrant angles of a boundary line, there are two partial height differences in one ordinate their sum is plotted.

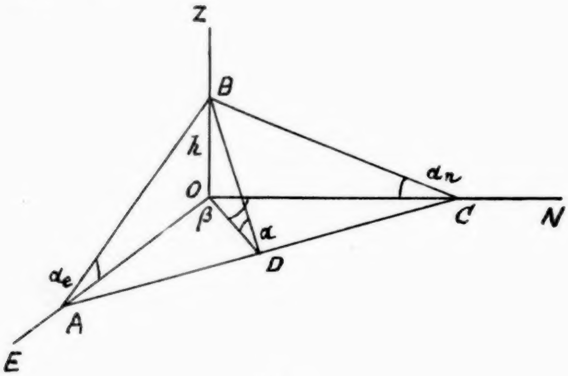

Fig. 4.

The interception by the topographical surface of the N.S. component of rainfall of any inclination will be the same as its interception by the horizontal projection P_z of the surface and the vertical projection P_n taken together. Similarly for the E.W. component and P_z with P_e. So that the topographical surface may be replaced by the surface of any plane figure of which the projection areas are also P_z, P_n, and P_e. If, in fig. 4, $AO\,.\,OC$ is made equal to P_z,

$$AO\,.\,OB=P_z\tan\alpha_n=P_n,\quad CO\,.\,OB=P_z\tan\alpha_e=P_e,\quad \text{and}\quad AC\,.\,BD=P$$

is therefore a surface of which the projections are P_z, P_n, and P_e. P may be called the equivalent area of the topographical surface and ABC the equivalent plane of its boundary. P, on this plane, is given by

$$P^2=P_z^2+P_n^2+P_e^2.$$

IV. Interpretation of Catches.

The inclination of rain is the resultant of the velocity of the wind and the rate of fall of the raindrops, which may be anything from 0 in a dry fog, 1 m./s. or less for snow or mist, 3 m./s. for fine rain, to 8 m./s. for the largest

drops (Brooke and Pagliuca (6), quoting Pers).* On mountains, at cloud levels in which misty rains prevail, the inclination may become almost horizontal, or even upwards, and extraordinary differences in equivalent rainfall result.

The neglect of this influence of the inclination of rain has been a fruitful source of error in the interpretation of some recorded catches. Thus, under the name of "condensation" of rain by vegetation, there has been attributed to vegetation some capacity of collecting more rain than would otherwise fall on the surface it covers or shields. J. F. V. Phillips (8) set up two 5-in. gauges, one as control, the other surmounted by a frame of wire-netting, 1 ft. high, filled with leafy branchlets. In one year the catch of the control was 50·02 in. and that of the "condensation" gauge 94·56 in. He attributed the increase to "condensation," particularly that of mists, which "precipitate large amounts of moisture upon cool surfaces, such as vegetation in its various forms, and on outcrops of rock along the mountain faces."

J. Phillips' figures do not afford the smallest indication that the increase in the "condensation" gauge was due to anything but the inclination of the rain.

Let d (fig. 5) be the diameter of the gauge, h the height of the intercepting cylinder of foliage, and i the inclination of the rain from the vertical.

* When they are very low, the settling velocities of raindrops may be computed from Stokes' formula put in the form

$$V = 2gr^2(\rho_p - \rho_f)/9\mu,$$

which gives the following values:—

d mm.	V m./s.	$\frac{Vl}{\nu}$
0·02	0·013	0·01
0·04	0·050	0·15
0·06	0·113	0·5
0·08	0·20	1·2

When the Reynolds number, Vl/ν, becomes large the formula ceases to be applicable. From Pers' data, referred to above, may be derived

$d=0{\cdot}3$ mm.	$V=1{\cdot}1$ m./s.	$Vl/\nu=$ 24
1·0 ,,	5·3 ,,	385

The diameter of the drops in ordinary rain is about 1·5 mm., for which $V=7$ m./s. approx.

The size of drops may be computed by the methods of Meteorological Optics from the optical effects they produce on light. According to Whipple (7) the size of the droplets producing the corona, which frequently appears when the moon is seen behind a thin cloud, averages about 0·02 mm. diameter, the range being from 0·01 to 0·06 mm. The drops in the falling rain which produce rainbows are usually larger, from 1·0 to 0·3 mm. in diameter, but the presence of supernumerary bows indicates the predominance of drops with diameter 0·25 to 0·05 mm.

Then

$$\left(\frac{\pi d^2}{4} + dh \tan i\right) \Big/ \frac{\pi d^2}{4} = \frac{C}{R},$$

where C is the catch of the "condensation" gauge and R that of the control, whence

$$\tan i = \frac{\pi}{4} \cdot \frac{d}{h}\left(\frac{C}{R} - 1\right).$$

In the example given,

$$\tan i = 0{\cdot}327\left(\frac{94{\cdot}56}{50{\cdot}02} - 1\right) = 0{\cdot}286,$$

making $i = 16°$.

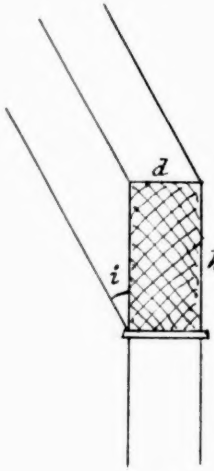

FIG. 5.

The surprising thing is not that the "condensation" gauge should have collected more than the control, but that it should have collected so little more, because, in the region experimented in, rain drives normally from the west at an angle which, to the eye, appears to be greater than 16°. One reason may have been that the cylinder of foliage was too open to intercept all the rain; another that the air streaming around it deflected some of the drops. Further loss may have been due to splashing and to the blowing away of part of the moisture before it could trickle down to the gauge. And there may have been some real "interception" of rain as understood by scientific experimenters.*

* "Interception of precipitation" is defined "as the process by which precipitation is caught and held by foliage, twigs and branches of trees, shrubs and other vegetation, and evaporated without reaching the ground" (11). It envisages a *loss* of rain to the

Marloth (9), some years previously, had conducted similar experiments on the top of Table Mountain (3500 ft.). He also used, over his collecting gauge, a frame of wire-netting, with the difference that, instead of foliage, he had inserted a number of restionaceous stems, which made a screen more permeable to the wind and draining more readily into the gauge, thus to a great extent avoiding the sources of error which affected J. Phillips' experiments, but introducing others that will be mentioned presently. Stewart (10), criticising Marloth's paper, was at some pains to measure accurately the superstructure of Marloth's gauge, but, not having considered quantitatively the effect of the inclination of the rain, could only conclude that "the problem is as far from being solved as before the experiments were undertaken."

The surface of the superstructure, consisting of rods, a ring, wire-netting, and restionaceous stems, was found to be 113·8 sq. in.,* equal to an intercepting surface of $113{\cdot}8/\pi = 36{\cdot}2$ sq. in. The receiving surface of the collecting gauge was contracted by the construction to 18·2 sq. in. against 19·6 sq. in. for the control (5-in.) gauge.

We have then C' and C being the catches in the reed and the control gauges, R the rainfall in the latter, and i the inclination of the rain to the vertical:

$$C' = 18{\cdot}25R + 36{\cdot}2 \tan i,$$
$$C = 19{\cdot}6R,$$
$$\frac{C'}{C} = 0{\cdot}932 + \bar{1}{\cdot}846 \tan i; \qquad \tan i = 0{\cdot}542\frac{C'}{C} - 0{\cdot}505.$$

Regarding the sources of error in Marloth's experiments:

(1) The particles of rain in the south-east cloud are very fine. Marloth himself says (14, p. 99), "Such a cloud is really an intimate mixture of an ordinary cloud with a very finely distributed rain in its initial stages." Textbooks of meteorology teach that clouds are really nothing else but fog or mist (except upper clouds composed of spiculae of ice). This is borne out by the experience of campers on mountains, and, in the present case, by the "Table-cloth" in which the particles of water driven over the edge of Table Mountain are so minute that they dissolve immediately the descending air stream they are carried in becomes slightly warmed up by adiabatic compression at a lower level.

(2) The small rate of fall of such particles, relatively to the high velocity of the south-east wind, causes the rain to drive at a very low inclination

soil, not a gain, as imagined by J. Phillips in letters entitled "Rainfall Interception by Plants" (12 and 13) which refer to his experiments noticed above, but entirely ignore real interception.

* "The result is well under the actual area," for reasons given by Stewart (10, p. 415).

to the horizontal. This being so, a glance at the photograph of the gauges on Table Mountain, reproduced in Marloth's first paper (9, p. 408), shows that when rain drives at this low angle, the control gauge and the reed gauge must both have been obstructed by higher bushes to the windward. This is further proved by recorded catches (Marloth (9), p. 406) of 15·22 and 14·64 in., and (Marloth (14), p. 102) of 9·55 and 0·15 in., in the reed gauge on days when the control collected nothing. Also by the fact that the open gauge at Maclear's beacon, close by, collected during one period (Marloth (9), p. 406) 6·99 in. against 4·97 in. in the control, and in another period (Marloth (14), p. 102) 9·55 in. against 1·44 in.

The data have now become too vague to yield any satisfactory determination of the inclination of the rain. All that can be done is to show that the catches are consistent with possible values of the rate of fall of the raindrops and of the velocity of the wind.

(3) During 56 days of the season of S.E. clouds, from December 21, 1902, to February 15, 1903, the control gauge collected 4·97 in., and the gauge with reeds 79·84, of which 29·86 in. were without any corresponding catch in the control, and, therefore, were due to rains from which both the control and the collecting base of the reed gauge were completely screened by bushes. The gauge at Maclear's beacon on the same mountain-top collected during the same period 6·99 in. of rain, and there is no reason to suppose that a properly exposed gauge near the reed gauge would have collected less. However, to depart least from the recorded figures and because the catch in the reed gauge was lost through a portion of the container having become full and overflowed on three occasions, a mean value of 5·98 in. is taken as a possible value of the catch of the control had it been properly exposed, an excess of 1·01 over the recorded catch, which must also be applied to the collecting base of the reed gauge, giving finally, as possible figures, 5·98 and 80·85 respectively. Then

$$\tan i = 0{\cdot}542\,\frac{80{\cdot}85}{5{\cdot}98} - 0{\cdot}505 = 6{\cdot}81,$$
$$i = 81^\circ\ 40'.$$

If the mean velocity of the S.E. wind was 20 mi./h. = 8·95 m./s., the rate of fall of the mist particles would be 8·95/6·81 = 1·3 m./s.

(4) In a second series of experiments, "near Maclear's beacon," for the month of January 1940, the control gauge showed only 1·44 in. of rain and the reed gauge 48·42, of which 9·70 were without any corresponding catch in the control. During the same period the catch at Maclear's beacon was 9·55 in. Taking as before the mean of 1·44 and 9·55 or 5·50 as the possible unobstructed catch of the control, and adding the 4·06

excess to the reed gauge, we get as possible values, with a large measure of uncertainty, 5·50 and 52·48 in. respectively. Then

$$\tan i = 0{\cdot}542 \frac{52{\cdot}48}{5{\cdot}50} - 0{\cdot}505 = 4{\cdot}60,$$
$$i = 77^\circ\ 40'.$$

For a wind velocity of 20 mi./h. the rate of fall of the mist particles would be $8{\cdot}95/4{\cdot}60 = 1{\cdot}9$ m./s.

(5) Two more series of observations were made, this time at the Woodhead Reservoir (alt. 2496 ft.), where at 1000 ft. lower elevation the raindrops would normally be larger.

One series, for the month of January 1904, gave 1·83 in. for the control, and for the reed gauge 13·73, of which 4·77 corresponded to only 0·02 in. in the first, leaving $13{\cdot}73 - 4{\cdot}77 = 8{\cdot}96$ in. caught in the reed gauge when $1{\cdot}83 - 0{\cdot}02 = 1{\cdot}81$ in. were collected in the control. Assuming, in the absence of any other indications, that the ratio of 1·81 to 8·96 would hold for unobstructed catches of the control and reed gauge, making these 2·23 and 13·73, and adding the excess $2{\cdot}23 - 1{\cdot}81 = 0{\cdot}42$ to the catch of the reed gauge, making it 14·15, we have

$$\tan i = 0{\cdot}542 \frac{14{\cdot}15}{2{\cdot}23} - 0{\cdot}505 = 2{\cdot}93,$$
$$i = 71^\circ\ 10'.$$

For a wind velocity of 20 mi./h. the rate of fall of the raindrops would be $8{\cdot}95/2{\cdot}93 = 3$ m./s., corresponding to fine rain, according to Pers' table previously cited.

(6) In the second series, for the month of January 1905, the catch in the control was 1·45 and in the reed gauge 15·86, of which 4·90 corresponded to only 0·04 in. in the first. Using again the ratio of the remainders for the total, and proceeding as in the last case, we get possible catches of 2·08 and 16·53 respectively, and

$$\tan i = 0{\cdot}542 \frac{16{\cdot}53}{2{\cdot}08} - 0{\cdot}505 = 3{\cdot}80,$$
$$i = 75^\circ\ 20'.$$

For a wind velocity of 20 mi./h. the rate of fall of the drops would be $8{\cdot}95/3{\cdot}80 = 2{\cdot}4$ m./s., still corresponding to fine rain.

The results of all four series of observations made by Marloth are therefore compatible with possible wind velocities in a "south-easter" and normal rates of fall of mist particles or raindrops, and give no support to his contention that vegetation condenses moisture, in addition to the

rainfall it mechanically receives. The catches given in Marloth's papers have been corrected, not because they would have led to different conclusions, but only because they were manifestly too small. Indeed, since the rate of fall of water particles may vary from 0 in a fog to 8 m./s. in heavy rain, and wind velocity is also variable, any ratio between the catches of a control and a "reed" gauge would be compatible with some rate of fall of the water particles and some velocity of the wind, within limits.

Marloth's observations, having been fundamentally vitiated by the incorrect exposure of his gauges to the rains of low inclination prevalent on Table Mountain, cannot be made to yield, even approximately, a true measure of the equivalent inclination of the rain for any of the periods considered. The numerical results they yield have been given merely to make clear, by examples, that enormous differences in the catches of control and "reed" gauges must result from rains of high inclination.

It might seem unnecessary to recall at this time of day this ancient controversy were it not that some South African botanists and others, notably J. Phillips (12, 13), Dyer (15), Levyns (16), and Wicht (17), still assume that Marloth "demonstrated" the reality of his conclusions.

Summary.

1. The factors which govern the catch of rain over a given area are shown to be the vertical rainfall, the inclination of the rain, its direction, and the slope and aspect of the ground. The mathematical relations between these five factors are deduced.

2. Methods of measuring the inclination and direction of rain are discussed and suitable gauges proposed.

3. Application is made to the determination of the true equivalent rainfall over a catchment area.

4. The neglect of the influence of the inclination of rain on the equivalent rainfall is shown to have been a fruitful source of error in the interpretation of some recorded catches.

Witte Els Bosch,
April 1941.

Addendum.

Since the above paper went to press, Dr. C. L. Wicht, Forest Research Officer at Jonkershoek, Stellenbosch, has had a multiple rain gauge constructed, substantially to the design proposed in the present paper, and with this, and another gauge with vertical apertures that is being made, intends to carry out an experimental investigation of the subject,

in connection with the studies of the hydrology of the Jonkershoek drainage basin on which he has been engaged for some years. His results, which necessarily cannot be immediate, will be awaited with interest.

Dr. Wicht's inclined gauge, of which fig. 6 is a photograph, is constructed with apertures at 45°, instead of 1 in 2, giving greater sensitiveness, while the addition of a vertical gauge makes it, in most cases, still possible to determine i_n and i_e when these, either or both, have exceeded + or − 45° some of the time. The supposition is that, on any gauge facing the

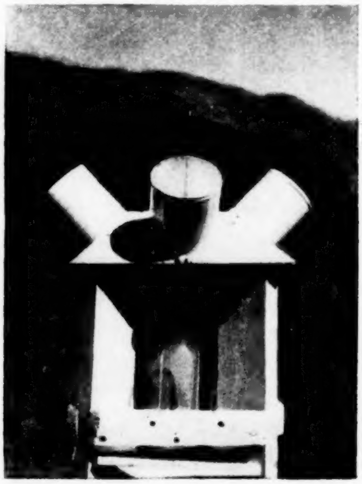

Fig. 6.

weather, the inclination component i has not varied beyond the limits of +90 and −45°, which may be valid from day to day, but not for extended periods.

Substitute, for the catches C, the equivalent vertical rainfall $r = C/a \cos a$, this being for 5-in. gauges at 45°, and C in cubic inches, $r = 0{\cdot}072\, C$. Then $\tan i_n$ may be derived from either $\frac{r_n - R}{R}$ if r_n is greater than r_s, or from $\frac{R - r_s}{R}$ if r_s is the greater, and similarly for $\tan i_e$.

Trial observations of the gauge were made at Jonkershoek from August 14 to September 23, 1941. On September 1, 17, and 22 the bottles overflowed. On August 15 and 20 the measures were inconsistent.

The following table gives particulars and results for the other days on which rain fell:—

1941.	R inches.	r_n.	r_s.	r_e.	r_w.	tan i_n.	tan i_e.	tan $\bar{\varpi}$.	$\bar{\varpi}$.	i.
Aug. 14	·59	1·28	·11	·16	1·27	1·17	− 1·15	− ·98	315° 30′	58° 30′
16	·01	·07	·01	·01	·05	insufficiently determinate				
18	·24	·07	·56	·46	·12	1·33	·92	·69	145 20	58 10
26	·04	·08	·02	·02	·11	1·00	− 1·75	− 1·75	299 40	63 40
29	·29	1·03	·03	·05	·98	2·54	− 2·38	− ·94	316 50	74 0
30	1·02	2·08	·24	·18	3·00	1·02	− 1·94	− 1·90	297 50	65 30
31	·22	·72	·03	·10	·53	2·27	− 1·41	− ·62	328 10	69 30
Sept. 2	1·00	2·74	·12	·51	1·80	1·74	− ·80	− ·46	335 20	62 30
3	·64	·97	·36	·69	·66	·52	·08	·15	8 40	28 0
13	·21	·37	·15	·10	·60	·76	− 1·86	− 2·45	292 10	63 30
14	·57	1·13	·15	·14	1·17	·69	− ·75	− 1·09	312 30	45 30
15	1·20	2·12	·51	·78	1·69	·77	− ·41	− ·53	332 0	41 0
16	·50	·76	·28	·30	·77	·52	− ·54	− 1·04	313 50	36 50
18	·39	·59	·24	·20	1·27	·51	− 2·26	− 4·43	282 40	66 40
19	·19	·19	·21	·17	·29	− ·11	− ·53	− 4·82	281 40	28 20
23	·45	·85	·72	·82	·31	·89	·82	·92	42 40	50 30

The method may be extended to cover continuous periods during which daily observations have been made. When the inclination of any of the rain components exceed $+45°$ the theoretical negative catches in the lee gauge of the pair are not recorded, so that, if $r_1 > r_2$, it may no longer be permissible to use the observed r_2, for which must be substituted a computed $r_2 = 2R - r_1$ in order to satisfy the necessary condition $\tan i = \frac{r_1 - R}{R} = \frac{R - r_2}{R}$. Conversely, if $r_2 > r_1$, r_2 observed and $r_1 = 2R - r_2$ computed must be used.

For example, taking the longest uninterrupted period in the above table, that from September 2 to September 16, the totals, after substitution of computed for observed figures where necessary, are $R = 4{\cdot}12$, $r_n = 8{\cdot}09$, $r_s = 0{\cdot}15$, $r_e = 1{\cdot}62$, and $r_w = 6{\cdot}62$. From these, $\tan i_n = 0{\cdot}964$, $\tan i_e = -0{\cdot}606$, $\tan \varpi = -0{\cdot}629$, $\varpi = 327°\ 50'$, and $i = 48°\ 40'$, R being the rainfall and ϖ and i the equivalent azimuth and inclination of the rain for the period.

Jonkershoek is a narrow valley running up, in a S.E. direction, between ranges of mountains from 4000 to 5000 feet high. The altitude of the station is not given, but it would be about 1000 feet.

The observations detailed above indicate that, at Jonkershoek:

1. The inclination of rain is frequently very great and comparable with the still greater values that were estimated for Table Mountain at a higher altitude.

2. The catches recorded could all be accounted for, on each day, by

rain components, persisting from one general direction at inclinations ranging from nearly horizontal, with gusts and fine or misty rain, to nearly vertical during lulls, so that negative inclinations produced by veering of the wind, if they did occur, are not likely to have exceeded $-45°$ on the one day.

3. A multiple gauge with apertures at 1 in 2 slope would be no better than one at 45° because, on account of the high inclination of some of the rain, it would still give catches C, or their corresponding rainfalls r, neither directly additive.

4. The multiple gauge with vertical apertures being free from this limitation is to be preferred, but the gauge at 45°, if the validity of the assumption made for the reductions can be confirmed, would remain useful for checking at times the working of the other.

5. It is possible that the rainfall recorded in the vertical gauge forming part of a multiple combination is systematically too low, by perhaps 5 or 10 per cent., and that a separate shielded gauge would yield more accurate results. Turbulence may be expected to be greater over the vertical gauge than over the gauges with vertical or inclined apertures because, on level ground, any wind will strike the aperture of a vertical gauge at a very small angle, while, in the other gauges, this can only happen when the wind actually blows from near one of the cardinal points.

WITTE ELS BOSCH,
November 1941.

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A SIMPLE FORM OF SLIT ULTRA-MICROSCOPE.

(*A Paper from the University of Cape Town.*)

By E. Newbery.

(With Plate XVIII and two Text-figures.)

(Read September 17, 1941.)

The slit ultra-microscope is generally recognised as the standard form of instrument for the study of colloidal suspensions when measurements of particle size and number are required, and its use has proved an important factor in the development of modern colloid chemistry. It suffers, however, from certain disadvantages, the chief of which is the high cost—about £100 to £150 for a complete outfit—which puts it out of reach of those of limited means. The Biltz cells generally used are also expensive and fragile, and the thin quartz windows are loosened from their settings if liquid is left in the cell for more than a few hours. These cells require several c.c. of liquid, and are rather difficult to fill owing to persistently sticking air bubbles.

Some of the dark-field illuminators on the market are less expensive and more convenient to use for qualitative observation of particles of colloidal dimensions, but are not adapted to quantitative measurements owing to the fact that the depth of the illuminating beam cannot be accurately determined.

Many individuals and institutions possess reasonably good microscopes with at least two objectives, but no appliances for ultra-microscopic work, and these may welcome the following suggestions whereby they may make such appliances at very small cost.

The Cell.—A number of different designs have been made and tested, but two only will be described here.

(1) A cube of ebonite, 1·5 to 2 cm. side, is mounted on a microscope slide, S (fig. 1), with the aid of soft wax or Canada balsam. In the middle of one edge a hole, 3 to 4 mm. diameter and the same depth, is drilled, the drill breaking through the side to form a **U**-shaped cavity, the edges of which are trimmed up with a small knife. A glass plate, F, is cemented on to this side of the cube with soft wax, the upper edge being carefully set flush with the top of the cube. This is done by applying a small

quantity of the wax to the ebonite, laying the glass on it, and brushing with a gas flame until all air bubbles have escaped. A thin cover-glass with one straight edge is laid loosely on top after filling the cell. If electrodes are required for this cell, a hole is drilled through the middle of the block and tapped to take the terminals T.T. A fine saw-cut is made across the top of the cell as shown by the dotted line in fig. 1, and a thin

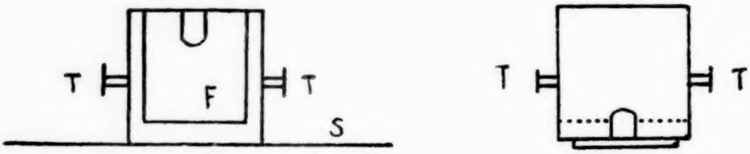


Fig. 1.

platinum wire is stretched between the terminals and bedded in the saw-cut with soft wax. This wire is then cut in the centre of the cell and the two ends bent down to form the required electrodes.

Such a cell holds about 0·1 c.c. of liquid and is suitable for most aqueous solutions, but not for strong alkalies or alcoholic solutions.

(2) A glass cell suitable for corrosive or wax-solvent liquids is shown in fig. 2. This consists of a glass tube about 1 cm. long and 3 mm. diameter,

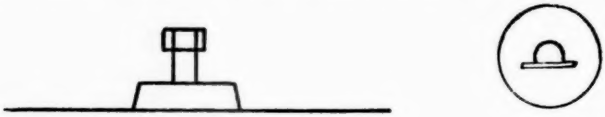


Fig. 2.

closed at one end and made D-shaped at the other by heating one side and flattening with small pliers. A small window of flat glass, about 4 mm. square, cut from a thin microscope slide, is cemented to the flattened side with Canada balsam, and the whole mounted on a microscope slide with the aid of a small cork. This window is necessary to avoid distortion of the condensed beam of light inside the cell. If the top of the cell is irregular, it may be rubbed down flat on emery cloth moistened with turpentine before fitting the window.

This cell is also covered with a small thin cover-glass after filling with liquid.

The Illuminator.—In the Zsigmondy type of slit ultra-microscope this consists of an arc lamp, a condensing lens, an adjustable slit, a second condensing lens, and finally a low-power microscope objective.

In the simplified apparatus here described, the first four of these are replaced by a low-voltage lamp bulb, preferably gas-filled, with as straight a filament as possible. This lamp is mounted with the filament horizontal in some form of adjustable stand (a small retort stand is suitable) which can be moved independently on the bench. Some kind of shade should be provided, and it must be possible to turn the lamp until the filament is vertical. Fitting the lamp socket through a cork in the end of a small can or bit of metal tubing fulfils both of these conditions.

The low-power objective of 10 to 20 mm. focal length is essential, but this is assumed to be part of the normal equipment of the microscope. This must be held in position in front of the cell by means of a second adjustable stand.

The main conditions to be fulfilled for good illumination are (1) high intrinsic brightness of the filament, and (2) very shallow depth of beam.

Of these, (1) is secured by using a small lamp bulb having a relatively high candle-power and running it with a small excess voltage. A good 6-volt motor-cycle rear light can stand 7 to 8 volts for a long period and is not expensive to replace if burnt out, but it is necessary carefully to select those bulbs which give a clear straight image of the filament when tested with a small lens and ground-glass screen.

Condition (2) is more difficult to fulfil when high magnifications are used. *The depth of the beam in the cell at the point of observation should not be greater than the depth of focus of the microscope.* If the beam is deeper than this, some particles will appear as hazy discs instead of bright specks, and accuracy of counting suffers. Irregularities in the glass of the lamp bulb may seriously interfere with the formation of a uniform beam.

The depth of the beam is diminished (1) by using a lamp with a thinner filament, (2) by increasing the distance between lamp and cell, and (3) by using a higher power condensing lens.

Of these, (1) and (2) diminish the intensity of the beam and (3) is limited in scope because a very short focus condensing lens must be placed so close to the cell that it gets in the way of the microscope objective.

Most high-C.P. low-voltage lamps have coiled filaments which give a somewhat thick beam. When using medium power objectives this is not troublesome, and the brilliance of illumination is so great that a dark room is unnecessary and a 6-volt lamp may be placed 10 cm. from the condenser. With higher power objectives, it may be necessary to remove the lamp to a distance of 50 cm. and then some darkening of the room is required. Extra lenses placed between the lamp and the condenser collect more light, but thicken the beam at the same time and are therefore of no advantage.

The Focusing Stand.—Although the focusing of the beam can be effected by supporting the lamp and condenser in separate stands and

moving them by hand on the working bench, this method is difficult when high-power objectives are used, the vertical adjustment being specially so. The best results are obtained when a X 40 water immersion objective is used together with a X 10 objective as condenser, and under these conditions some form of mechanical focusing is a great convenience.

The apparatus shown in Pl. XVIII, figs. 1 and 2, is easily constructed at small cost, and has proved very effective. A brass bar $\frac{5}{16}$ in. square and 18 in. long forms the optical bench and carries the adjustable condenser holder at one end, the construction of which is evident from the figures. About 2 in. from this end the bar is pivoted on a $\frac{1}{8}$-in. brass rod held in a small stand with L-shaped base. The lower end of the vertical rod of this stand is sharply pointed to prevent slipping on the bench, and the two arms of the base carry levelling screws tipped with small steel balls. These arms, as shown in the figure, were made of iron bars, $7 \times 1 \times \frac{1}{8}$ in., one of them being weighted with a block of lead to secure steadiness. If bars $\frac{1}{2}$ in. instead of $\frac{1}{8}$ in. are used, and one end of each cut to form a lapped joint, no further weighting is required and holes for the levelling screws may be tapped directly through the bars.

It will be seen that vertical adjustment of the beam is effected by the screw on top of the condenser holder, focusing of the beam by the levelling screw on the left, and cross adjustment by the levelling screw in front.

The other end of the brass bar is supported on a $\frac{1}{8}$-in. brass rod sliding freely in a hole drilled about $1\frac{1}{2}$ in. down the centre of the bar. The stand on the left of Pl. XVIII, fig. 2, holding this rod, consists of a lead block with a $1\frac{1}{4}$-in. brass upright held by two nuts, one of them a thumbscrew.

The lamp-holder consists of a short piece of brass tubing with brass washers soldered on at each end. The loose ring of a small B.C. lamp socket is soldered into one end of the tube, and the whole is held on to the bar by means of a spiral spring passing through a hollow roller on top of the bar. The spacing device shown is a small brass framework, but a piece of hard wood suitably grooved to fit the bar on top and the brass tube underneath is quite suitable and easily made. Marks are made on one of the washers to indicate the direction of the lamp filament. By means of the thumbscrews on the bases of both stands, the whole apparatus can be dismantled and packed into a box, $24 \times 3 \times 3$ in., along with half-dozen cells, spare lamps, cover-glasses, etc. The total cost of the materials used in constructing this apparatus including stands, 3 ebonite and 3 glass cells, and one lamp was about five shillings.

Other Equipment.—For determination of particle size, etc., it is essential for the eyepiece of the microscope to be fitted with a cross-line micrometer, and a stage micrometer (1 mm. divided into 1/100 mm.) is also required. These may be purchased at approximately ten shillings each, but the

former can be made without great difficulty by drawing a grid, 6 × 3 cm. (18 squares of 1 cm. side), with indian ink in the middle of a large sheet of white paper on a drawing-board, and photographing it so that the grid appears about 2 × 1 mm. A slow process plate should be used, and a print made on a small piece of flat film, discs to fit the eyepiece being cut from the film with a cork borer. The grid will probably be in focus when the disc is laid on the stop in the eyepiece and held in position with a wire ring, but if not, the focus may be adjusted by means of suitable washers of paper or thin card. The stage micrometer can also be made by a similar process, but is a much more difficult operation owing to the need for greater accuracy, and is not recommended.

Performance.—Experiments were carried out with two sols, one of gamboge containing 100 mg. per litre, prepared by pouring an alcoholic solution into water, and one of metallic gold containing 20 mg. per litre prepared by von Weimarn's method. The gamboge sol gave an average of 1·51 particles per square of the eyepiece grid, when the depth of the beam was covered by the sides of two squares. The side of 3 squares was found to coincide with 0·02 mm. on the stage micrometer, and the density of the solid gamboge was 1·3.

From these data, the diameter of the particles, assumed to be spherical, is found to be approximately 320 mμ.

The freshly prepared gold sol gave an average of 2·5 particles per square, in vigorous Brownian movement. Taking the density of gold as 19·3, the mean diameter of the particles is found to be 65 mμ. These results compare very reasonably with those obtained by other investigators with similar sols.

Summary.

A simplified type of slit ultra-microscope is described which can be constructed by an amateur having reasonable workshop facilities, at a fraction of the cost of the standard commercial apparatus, it being assumed that an ordinary microscope with two objectives is already available.

The cells described are easy to fill, require only 0·1 to 0·3 c.c. of liquid, and may be fitted with electrodes if required, but, unlike the Biltz cells, they must be removed from the stage for re-filling. The illuminated slit of the Zsigmondy apparatus is replaced by the filament of a small electric lamp.

The Council desires to acknowledge the receipt of a grant from the University of Cape Town towards the cost of publication of this paper.

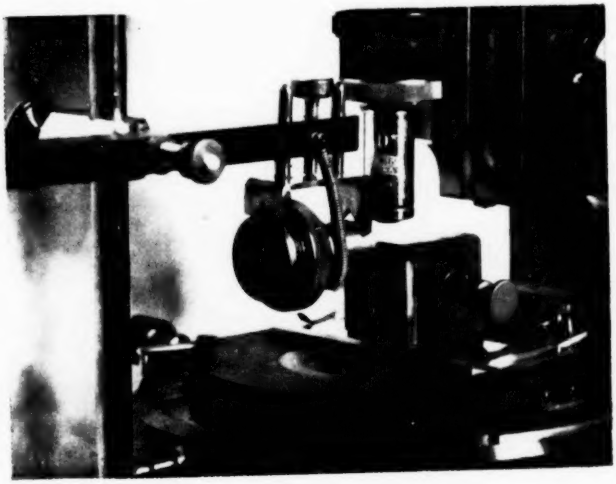


Fig. 1.

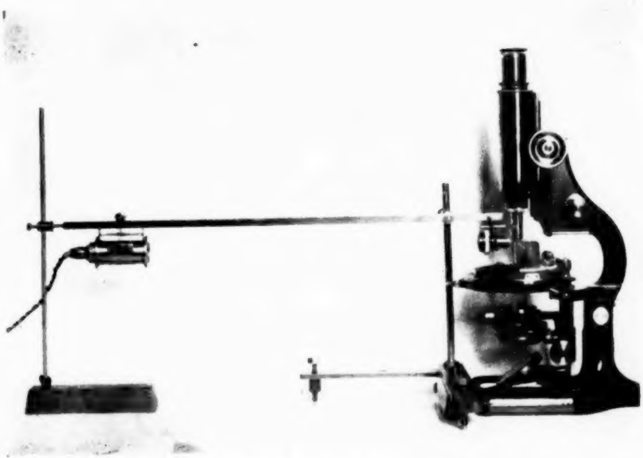


Fig. 2.

E. Newbery. Neill & Co., Ltd.

MAGNETIC OBSERVATIONS AT THE SECULAR VARIATION FIELD STATIONS IN THE UNION OF SOUTH AFRICA AND SOUTH WEST AFRICA, AND A COMPARISON WITH CORRESPONDING VALUES AT THE MAGNETIC OBSERVATORY, CAPE TOWN.

By A. Ogg.

(With four Text-figures.)

(Read September 17, 1941.)

Field Observer: K. W. Simpson.
Observatory Officers: B. Gotsman and A. M. van Wijk.
Field Instruments: Quartz Horizontal Intensity Magnetometer (la Cour Q.H.M. No. 29).
Magnetic Balance (la Cour B.M. No. 10).
Askania Declinometer (578179).

The importance of secular variation observations for obtaining a picture of the changes of the earth's magnetic field has been repeatedly emphasised by the International Association for Terrestrial Magnetism and Electricity. A Committee of the Association published a report * on the subject and made suggestions about tentative repeat stations.

It was decided to undertake this work in Southern Africa but to adopt a much more elaborate programme than that suggested by this Committee as a minimum.

The success of this magnetic survey is due to the selection of the la Cour instruments for field observations and their accurate manipulation by the field observer under varying weather conditions. The suitability of the la Cour instruments for field observations has been discussed in two papers † and the progress of this work in South Africa in a report ‡ to the International Association for Terrestrial Magnetism.

Forty-four stations, fairly uniformly distributed throughout the Union of South Africa and South West Africa have been fixed and their trigonometrical data determined. The districts for these stations were selected to give a good distribution, and the field observer finally chose the site after

* Bulletin No. 9 Comptes Rendus de l'Assemblie de Lisbon, 1933.

† Trans. Roy. Soc. S. Africa, vol. xxvi, p. 395, 1938, and vol. xxvii, p. 223, 1939.

‡ Trans. Washington Meeting, Sept. 1939, p. 124.

careful consideration of the neighbourhood and probable developments therein. A full programme of magnetic measurements has been made at each station, and the stations were magnetically "tied" to the magnetic observatory at Cape Town, but now to the magnetic observatory at Hermanus, Cape Province.

To obtain accurate secular variation data, exact reoccupation of a station is necessary, particularly in a country where many magnetic anomalies exist. To secure this a cylindrical non-magnetic concrete pillar has been erected at each station to carry the instruments. Sketches and photographs of each station, showing the roads leading to the station and the beacons of known azimuth, which were used in the survey, are now available at the observatory for future use. This information should facilitate a reoccupation and greatly shorten the time necessary for the observations.

One important difference in this magnetic survey from former surveys is the determination of magnetic intensities and declination as means of about forty observations taken over a period of about ten hours. The field observer, with the help of a native assistant, made about forty observations of horizontal intensity and of vertical intensity fairly evenly spaced over the period. This programme is a heavy one, but it was carried out with success, as the results testify.

The Q.H.M. gives not only horizontal intensities but also relative values of declination from the "zero torsion" position of the magnetic needle. These relative values are converted into absolute values by declinometer determinations immediately before and after the series of Q.H.M. observations.

The results of the survey have been tabulated in a form to give trigonometrical data; date and time of observations; mean values of declination, horizontal intensity and vertical intensity; difference between the mean values at Cape Town and the station; time of maximum and minimum values; ranges and magnetic character of the day of observation.

Graphs of the observations taken at each station and of the magnetic values taken from the observatory magnetograms show very good agreement. Figs. 1, 2, 3, and 4 are typical graphs: figs. 1 and 2 for quiet days; fig. 3 for a slightly disturbed day, and fig. 4 for a disturbed day of considerable range.

The graphs of vertical intensity are not shown, because the magnetograms of vertical intensity were so disturbed by the electric railways that the intensity measurements were taken from smoothed curves.

On quiet days the maximum and minimum points of the graphs lie within the period 06^h to 16^h G.M.T., and it is found that, since the magnetograms are comparatively flat during the night, the mean value for this

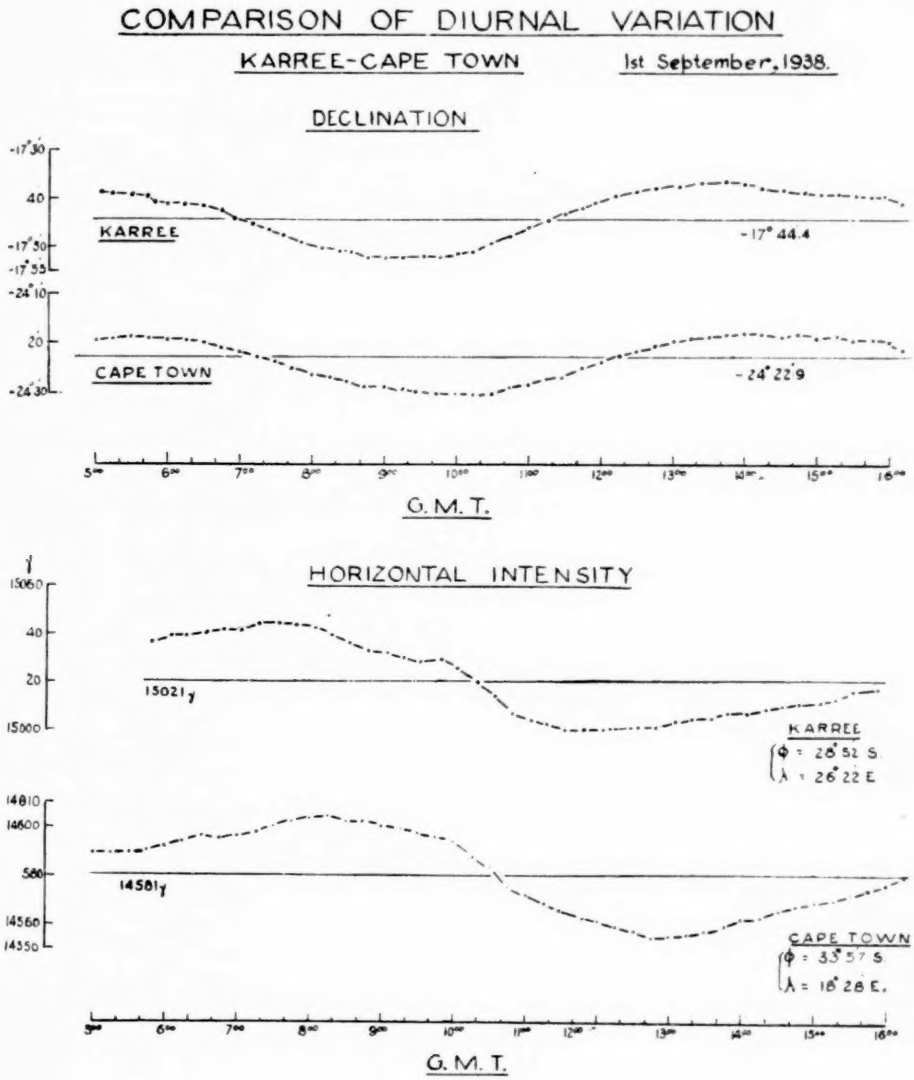
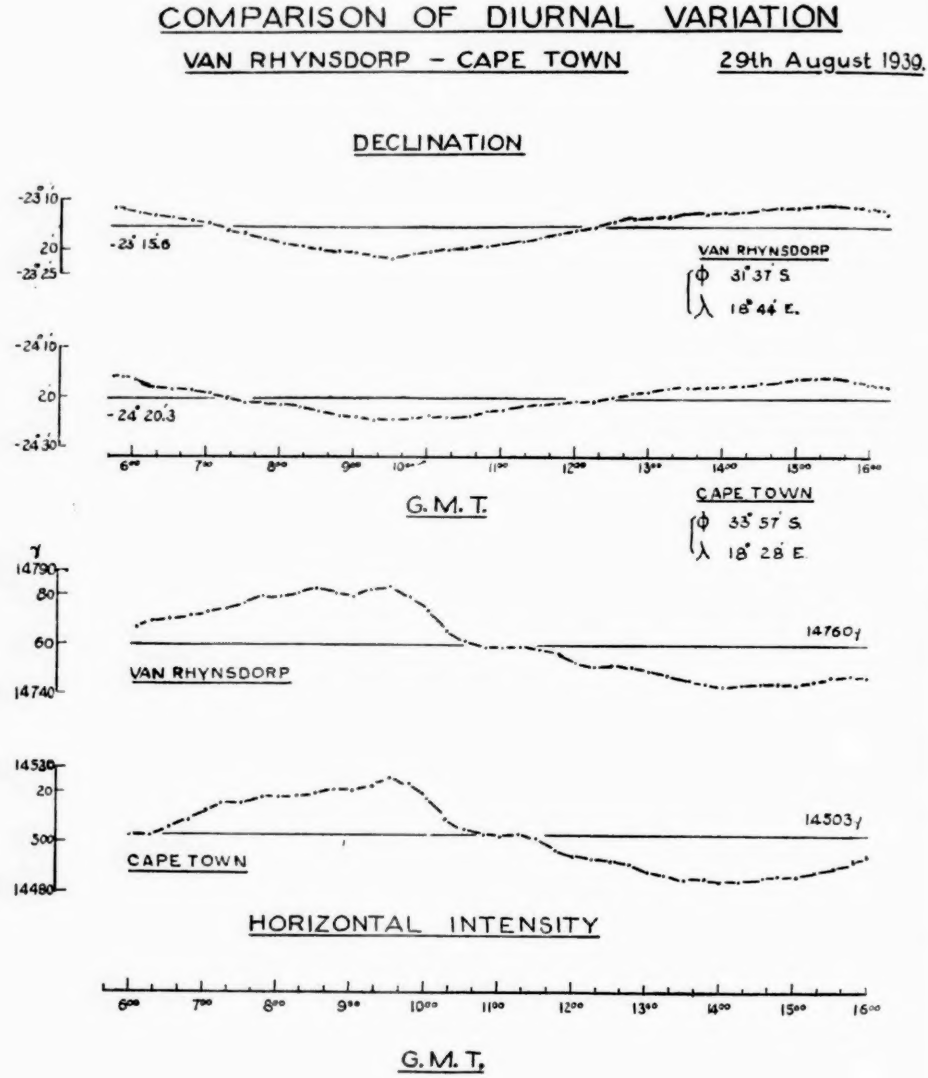

COMPARISON OF DIURNAL VARIATION
KARREE-CAPE TOWN
1st September, 1938.
DECLINATION
KARREE
-17° 44.4
CAPE TOWN
-24° 22.9
G. M. T.
HORIZONTAL INTENSITY
15021γ
KARREE
φ = 28° 52 S.
λ = 26° 22 E.
14581γ
CAPE TOWN
φ = 33° 57 S.
λ = 18° 28 E.
G. M. T.

FIG. 1.



COMPARISON OF DIURNAL VARIATION
VAN RHYNSDORP - CAPE TOWN
29th August 1939.
DECLINATION
-23° 10'
20'
-23° 25'
-23° 15.6'
VAN RHYNSDORP
φ 31° 37' S.
λ 18° 44' E.
-24° 10'
20'
-24° 30'
-24° 20.3'
6⁰⁰ 7⁰⁰ 8⁰⁰ 9⁰⁰ 10⁰⁰ 11⁰⁰ 12⁰⁰ 13⁰⁰ 14⁰⁰ 15⁰⁰ 16⁰⁰
G. M. T.
CAPE TOWN
φ 33° 57' S.
λ 18° 28' E.
γ
14790
80
60
14740
14760γ
VAN RHYNSDORP
14530
20
500
14480
14503γ
CAPE TOWN
HORIZONTAL INTENSITY
6⁰⁰ 7⁰⁰ 8⁰⁰ 9⁰⁰ 10⁰⁰ 11⁰⁰ 12⁰⁰ 13⁰⁰ 14⁰⁰ 15⁰⁰ 16⁰⁰
G. M. T.

FIG. 2.

period agrees closely with that for the period 0^h to 24^h G.M.T. This will hold also for field stations on quiet days.

In order to have observations at each station on a "zero" day, the field observer did not leave any station until he received telegraphic instructions from the observatory either to repeat observations or to proceed to the next station.

When secular variation is derived from one or two observations at a station it is necessary to make corrections for diurnal variations, which depend on the magnetic characters of the days of observation. In order to avoid the errors and difficulties of making such corrections, it was decided to adopt the method of finding mean values on quiet days. However, as the work proceeded, it was found that observations on disturbed days were satisfactory, if the disturbances were not of large range.

Quiet Day and Disturbed Day Observations.

This survey has shown that the difference between the mean values at the observatory and at a station may be taken to be the same on a disturbed day (excepting a very disturbed day at a distant station) as on a quiet day. As the range of a magnetic storm depends on the geographical position of the station, very disturbed days at distant stations must be excluded.

There were nine stations at which full-period observations were taken on a disturbed day and on a quiet day.

The {Difference of Mean Values (C.T. – F.S.) on the Disturbed Day} minus the {Difference of Mean Values (C.T. – F.S.) on the Quiet Day} varied from

– D.	H.	Z.
$+1'{\cdot}6$ to $-2'{\cdot}4$ (mean $-0'{\cdot}7$).	$-23\,\gamma$ to $+11\,\gamma$ (mean $+1\,\gamma$).	$+13\,\gamma$ to $-21\,\gamma$ (mean $+1\,\gamma$).

Declination.—The agreement is very good even on international disturbed days at distant stations.

Horizontal Intensity.—One extreme value, $-23\,\gamma$, was at Messina in the northern Transvaal, and the other, $+11\,\gamma$, at Otavi and Gobabis in the north and north-east of S.W. Africa. In each case the day of observation was an international disturbed day. Both Messina and Otavi are over 1000 miles from Cape Town, and the absolute values $3125\,\gamma$ and $4378\,\gamma$, respectively, greater than at Cape Town. Gobabis is over 800 miles from Cape Town, and the absolute value $2980\,\gamma$ greater. At the other six stations the differences varied from $+7\,\gamma$ to $-7\,\gamma$ (mean $+2\,\gamma$).

Vertical Intensity.—The extreme value, $-21\,\gamma$, was at Gobabis on an international disturbed day. At the other eight stations the differences varied from $+13\,\gamma$ to $-9\,\gamma$ (mean $+4\,\gamma$).

At three stations, Upington, Springbok, and Luderitz, there were

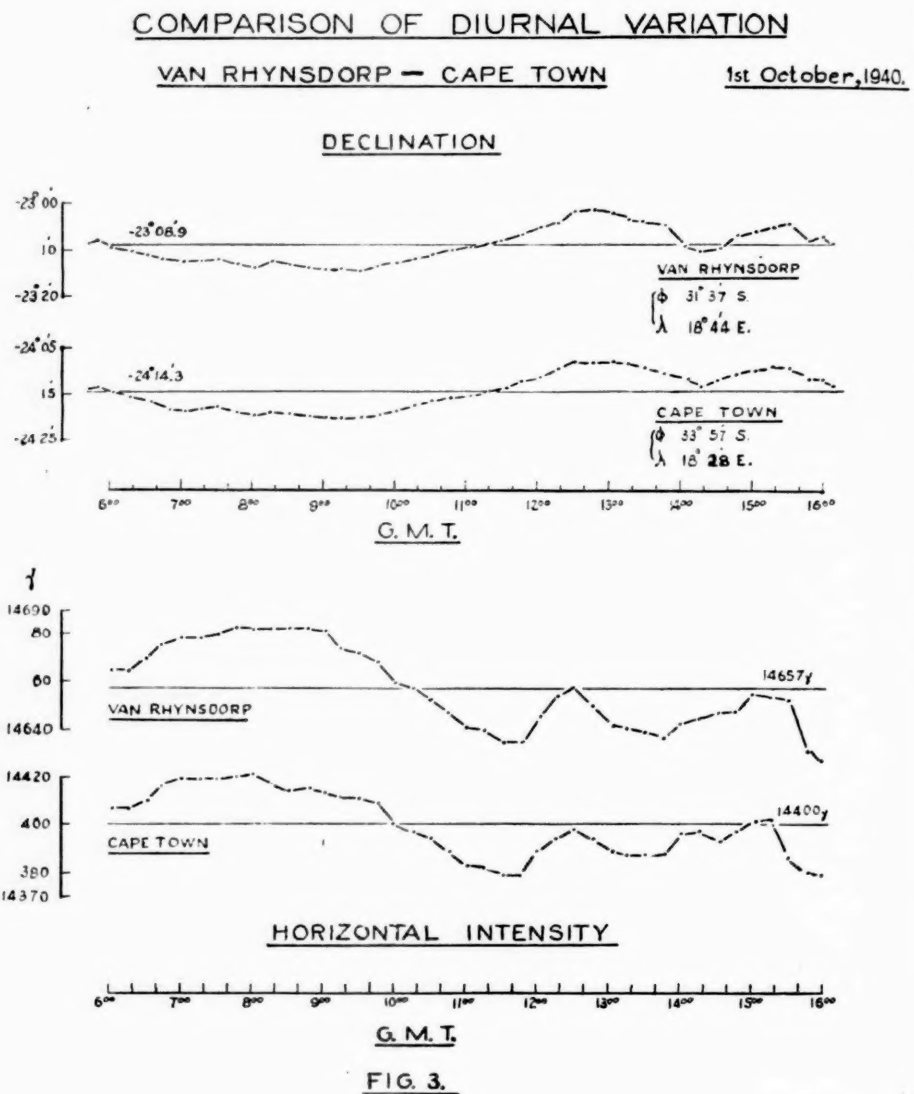

COMPARISON OF DIURNAL VARIATION
VAN RHYNSDORP — CAPE TOWN
1st October, 1940.
DECLINATION
-23° 00′
10
-23° 20′
-23° 08.9′
VAN RHYNSDORP
φ 31° 37′ S.
λ 18° 44′ E.
-24° 05′
15
-24° 25′
-24° 14.3′
CAPE TOWN
φ 33° 57′ S.
λ 18° 28′ E.
6⁰⁰ 7⁰⁰ 8⁰⁰ 9⁰⁰ 10⁰⁰ 11⁰⁰ 12⁰⁰ 13⁰⁰ 14⁰⁰ 15⁰⁰ 16⁰⁰
G. M. T.
γ
14690
80
60
14640
14657γ
VAN RHYNSDORP
14420
400
380
14370
14400γ
CAPE TOWN
HORIZONTAL INTENSITY
6⁰⁰ 7⁰⁰ 8⁰⁰ 9⁰⁰ 10⁰⁰ 11⁰⁰ 12⁰⁰ 13⁰⁰ 14⁰⁰ 15⁰⁰ 16⁰⁰
G. M. T.

FIG. 3.

COMPARISON OF DIURNAL VARIATION

16 August, 1939. UPINGTON – CAPE TOWN

DECLINATION

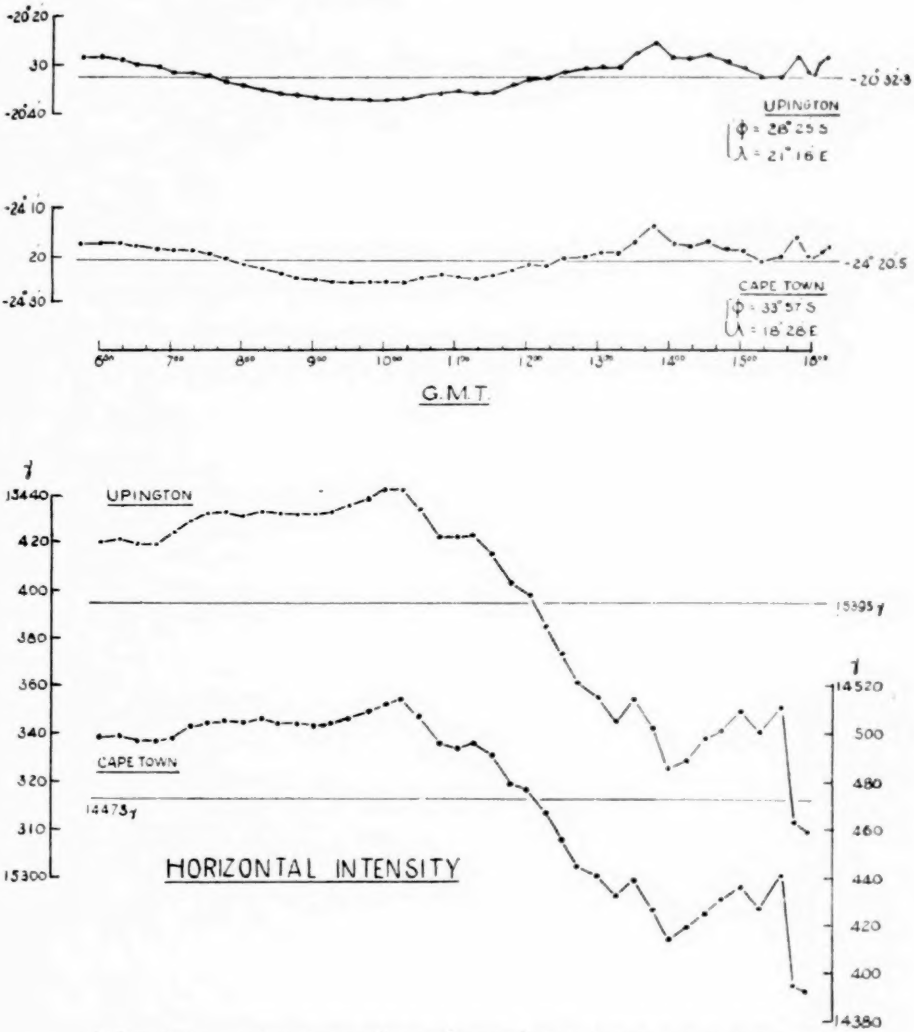


FIG. 4

full-period observations on a disturbed day and half-period observations on a quiet day. The agreement in declination and horizontal intensity was good in all cases. In vertical intensity the agreement was good at two stations, but at Luderitz there was a difference of 22 γ.

$$1\,\gamma = 10^{-5} \text{ Gauss.}$$

Quiet Days.

At five stations there were full-period (about ten hours) observations on two quiet days; at four stations full-period one day and half-period another day; at two stations half-period on two days. Since the two days of observation are of the same magnetic character the deviation of the mean value (C.T. − F.S.) for each day from the mean for the two days has been calculated. The results for the observations on the two days are in good agreement. The mean deviation for all the stations are: Declination 1′, Horizontal Intensity 2 γ, Vertical Intensity 4 γ.

It is clear from the observations in this magnetic survey that, from the mean of a series of magnetic observations at a secular variation station on a quiet or moderately disturbed day and the mean of corresponding observations at the magnetic observatory, accurate secular variations may be determined.

The absolute values at the magnetic observatory vary from day to day due to changes of the external field, but at the stations, which have been surveyed, similar changes are taking place. The difference between the observatory values and the station values have now been established at definite dates. The secular variation can then be determined from the differences at some future date and the known secular variation at the observatory.

As an illustration we may refer to the observations at Van Rhynsdorp on 29th and 30th August 1939, and on 30th September and 1st October 1940. It is evident from these that the secular variations of Declination and of Horizontal Intensity at Van Rhynsdorp for the year September 1939 to September 1940 are the same as at Cape Town. If the Vertical Intensity values are correct, the Z variations are different and the difference can easily be calculated. There is, however, some doubt about the Z variation.

During the magnetic survey from August 1938 to April 1939 there was a small increase of 9 γ in the constant of the magnetic balance, but from April 1939 to September 1940 there was a further increase of 32 γ, although the balance had not been used for field observations. The balance is now regularly standardised at the observatory to see if such changes are going on.*

* Note added 30th May 1942. In calculating the Z values at Van Rhynsdorp in 1940 the constant of the balance, determined in September 1940, was used. As the

Magnetic observations at Van Rhynsdorp on 1st October 1940 were undertaken to see if any magnetic effects during the total solar eclipse could be detected. Observations of declination, horizontal intensity, and vertical intensity were taken on the day of the eclipse, on the day before, and on the day after. Fig. 3 shows that there were magnetic disturbances on the day of the eclipse, but they were not confined to the eclipse belt. The magneto grams at Cheltenham, U.S.A., copies of which were kindly sent to me by the Director of the U.S. Coast and Geodetic Survey, show disturbances over the same period.

balance had not again been standardised for temperature, the old temperature coefficient was used in the calculations. Recent standardisations by A. M. van Wijk have shown that the temperature coefficient of the instrument has also changed. The temperatures at Van Rhynsdorp in 1940 were 10° C. higher than in 1939. Owing to this change of temperature coefficient a considerable correction has to be applied to the 1940 values given in these tables. The corrected values are: September 30, $-145\ \gamma$; October 1, $-147\ \gamma$; October 2, $-141\ \gamma$; mean $-144\ \gamma$.

This value agrees with the mean value $-141\ \gamma$ found in 1939. From these observations we can state that the secular changes of Declination, Horizontal Intensity, and Vertical Intensity at Van Rhynsdorp during the period from 1st September 1939 to 1st October 1940 were the same as at Cape Town Observatory.

[Tables.

MAGNETIC OBSERVATIONS AT THE SECULAR VARIATION FIELD STATIONS AND THE CORRESPONDING VALUES AT THE MAGNETIC OBSERVATORY, CAPE TOWN.

Greenwich Mean Time.

Field Station (F.S.) and Magnetic Observatory, Cape Town (C.T.).	Lat. S.	Long. E.	Date. 1938.	Time of Obs.	Mean Values.			Difference of Mean Values. C.T. – F.S.			Range of Extreme Values (R). D.			Range of Extreme Values (R). H.			Character.
					– D.	H.	– Z.	– D.	H.	Z.	Max.	Min.	R.	Max.	Min.	R.	
	° ′	° ′		h. m.	° ′	γ	γ	° ′	γ	γ	h. m.	h. m.	′	h. m.	h. m.	γ	
Matjesfontein "A" Cape Town . .	33 14 33 57	20 35 18 28	Aug. 5 ,,	06 10 to 15 30	23 36·4 24 25·7	14316 14555	29652 29349	+ 0 49·3	+ 239	+ 303	05 43 05 43	10 03 10 28	14·7 14·5	07 26 07 44	14 16 14 16	70 66	1
Matjesfontein "A" Cape Town . .			Aug. 8 ,,	06 10 to 16 10	23 37·8 24 25·5	14347 14588	29643 29353	+ 0 47·7	+ 241	+ 290	14 20 15 18	09 40 10 00	16·7 13·6	09 48 09 48	13 48 13 48	63 66	0*
Beaufort West "B" Cape Town . .	32 20	22 35	Aug. 13 ,,	06 05 to 15 45	22 17·5 24 28·1	14519 14577	29564 29348	+ 2 10·6	+ 58	+ 216	14 30 14 48	09 54 10 18	19·6 16·0	07 48 07 48	13 33 13 48	77 71	0
Hutchinson . . Cape Town . .	31 30	23 12	Aug. 18 ,,	05 55 to 15 45	21 40·2 24 23·1	14669 14588	29633 29334	+ 2 42·9	– 81	+ 299	14 20 14 48	10 30 10 00	11·0 9·1	07 54 08 20	13 26 13 20	40 38	0* Q
Springfontein . Cape Town . .	30 15	25 43	Aug. 25 ,,	06 00 to 15 30	20 39·8 24 24·8	14501 14581	29867 29343	+ 3 45·0	+ 80	+ 524	14 40 15 08	09 30 09 30	16·1 13·3	07 48 08 16	13 32 14 00	58 60	0
Karee "C" . . Cape Town . .	28 52	26 22	Sept. 1 ,,	05 45 to 16 00	17 44·4 24 22·9	15021 14581	29673 29341	+ 6 38·5	– 440	+ 332	13 44 14 04	09 04 10 04	16·2 11·9	07 28 08 16	12 12 12 52	44 49	0* Q
Orange River . Cape Town . .	29 40	24 12	Sept. 8 ,,	05 45 to 16 00	20 12·8 24 25·3	14892 14579	29609 29332	+ 4 12·5	– 313	+ 277	13 48 14 36	08 56 09 36	21·3 21·0	07 48 07 40	12 04 12 00	46 46	0*
Warrenton . . Cape Town . .	28 07	24 52	Sept. 15 ,,	05 45 to 09 30	19 27·1 24 19·6	15158 14514	29878 29343	+ 4 52·5	– 644	+ 535	Dust storm stopped observations.						2 D
Warrenton . . Cape Town . .			Sept. 16 ,,	05 40 to 16 00	19 32·4 24 26·9	15188 14546	29887 29353	+ 4 54·5	– 642	+ 534	15 25 15 15	08 10 08 40	10·2 10·8	09 33 10 00	14 35 14 15	37 35	0

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											D.			H.			
					– D.	H.	– Z.	– D.	H.	Z.	Max.	Min.	R.	Max.	Min.	R.	
	° ′	° ′		h. m.	° ′	γ	γ	° ′	γ	γ	h. m.	h. m.	′	h. m.	h. m.	γ	
Mafeking . . . Cape Town . .	25 52 33 57	25 40 18 28	Sept. 22 ,,	05 00 to 16 00	17 41·3 24 22·8	16058 14580	29459 29352	+ 6 41·5	–1478	+ 107	12 00 13 00	07 00 09 30	7·7 7·4	06 40 07 00	14 48 14 00	57 51	0
Muldersdrift . . Cape Town . .	26 02	27 53	Oct. 6 ,,	05 20 to 16 00	16 54·4 24 23·0	15936 14593	29633 29325	+ 7 28·6	–1343	+ 308	12 32 12 45	07 33 08 00	13·0 14·1	06 48 06 30	13 30 13 15	53 42	1
Muldersdrift . . Cape Town . .			Oct. 18 ,,	05 45 to 16 00	16 52·9 24 24·9	15938 14588	29621 29327	+ 7 32·0	–1350	+ 294	12 48 14 00	07 04 08 00	10·7 14·3	08 05 06 45	15 00 11 15	59 38	0*
Muldersdrift . . Cape Town . .			Oct. 19 ,,	07 00 to 15 25	16 53·4 24 23·4	15924 14574	29625 29328	+ 7 30·0	–1350	+ 297	12 20 13 45	08 05 08 30	12·0 12·8	07 05 06 45	13 20 13 20	28 44	0*
Muldersdrift . . Cape Town . .			Oct. 24 ,,	07 02 to 15 53		15912 14563			–1349					Q.H.M. No. 30			1
Parys . . . Cape Town . .	26 56	27 25	Oct. 13 ,,	05 30 to 16 15	17 58·3 24 23·8	15061 14596	29767 29328	+ 6 25·5	– 465	+ 439	13 00 14 15	07 15 07 50	12·6 14·0	07 20 07 30	12 35 12 15	33 29	0
Parys . . . Cape Town . .			Dec. 6 ,,	12 30 to 16 00	17 55·6 24 17·9	15021 14566	29759 29320	+ 6 22·3	– 455	+ 439							0*
Parys . . . Cape Town . .			Dec. 7 ,,	06 00 to 09 00	17 59·4 24 28·3	15051 14590	29756 29314	+ 6 28·9	– 461	+ 442							0*
Machadodorp . . Cape Town . .	25 40	30 15	Oct. 28 ,,	06 00 to 15 45	16 07·1 24 23·2	16054 14554	29711 29330	+ 8 16·1	–1500	+ 381	12 28 13 00	07 20 08 30	13·4 17·2	07 40 07 40	13 25 13 35	54 44	0

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Greenwich Mean Time.

Field Station (F.S.) and Magnetic Observatory, Cape Town (C.T.).	Lat. S.	Long. E.	Date. 1938.	Time of Obs.	Mean Values.			Difference of Mean Values. C.T. – F.S.			Range of Extreme Values (R).						Char-acter.
											D.			H.			
					– D.	H.	– Z.	– D.	H.	Z.	Max.	Min.	R.	Max.	Min.	R.	
	° ′	° ′		h. m.	° ′	γ	γ	° ′	γ	γ	h. m.	h. m.	′	h. m.	h. m.	γ	
Boane (Portuguese) Cape Town . .	26 02 33 57	32 20 18 28	Nov. 2 ,,	05 40 to 16 00	14 53·5 24 22·8	15968 14580	30176 29324	+ 9 29·3	– 1388	+ 852	12 05 14 15	06 20 08 15	16·6 19·6	08 10 06 40	16 00 16 00	51 54	0
Boane . . Cape Town . .			Nov. 3 ,,	06 00 to 15 45	14 56·6 24 24·4	15963 14574	30170 29323	+ 9 27·8	– 1389	+ 847	12 40 13 45	07 00 08 00	16·6 19·6	07 45 07 20	15 30 14 45	36 38	0* Q
Mica . . . Cape Town . .	24 10	30 50	Nov. 10 ,,	05 40 to 16 00	14 43·4 24 23·3	16701 14554	29481 29322	+ 9 39·9	– 2147	+ 159	12 35 13 30	07 20 07 15	12·3 12·7	08 45 08 00	13 05 12 00	26 32	0
Messina . . Cape Town . .	22 21	30 02	Nov. 17 ,,	05 40 to 16 10	13 34·5 24 22·6	17706 14570	29405 29314	+ 10 48·1	– 3136	+ 91	12 25 14 55	05 40 07 10	16·9 21·8	12 25 12 20	15 10 15 10	144 94	1 D
Messina . . Cape Town . .			Nov. 18 ,,	06 00 to 16 00	13 35·4 24 24·4	17671 14558	29411 29330	+ 10 49·0	– 3113	+ 81	11 35 16 00	06 20 08 00	14·6 11·6	08 00 08 45	12 25 12 25	34 42	0
Tomburke . . Cape Town . .	23 04	28 00	Nov. 24 ,,	06 00 to 09 00	16 45·9 24 30·1	17314 14575	29582 29332	+ 7 44·2	– 2739	+ 250	Observations stopped because of high temperature.						0
Tomburke . . Cape Town . .			Nov. 25 ,,	09 15 to 14 00	16 35·4 24 19·8	17273 14535	29573 29316	+ 7 44·4	– 2738	+ 257							0
Potgietersrust . Cape Town . .	24 11	29 01	Nov. 30 ,,	06 00 to 15 55	14 33·7 24 22·3	16537 14580	29400 29307	+ 9 48·6	– 1957	+ 93	12 05 14 00	05 45 06 45	17·5 14·6	08 45 08 45	13 00 13 10	44 44	0* Q
Potgietersrust . Cape Town . .			Dec. 2 ,,	06 05 to 16 00	14 32·5 24 20·9	16541 14581	29409 29315	+ 9 48·4	– 1960	+ 94	12 30 13 00	06 00 08 00	15·4 17·5	08 15 08 15	16 00 15 50	112 89	2 D

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Greenwich Mean Time.

Field Station (F.S.) and Magnetic Observatory, Cape Town (C.T.).	Lat. S.	Long. E.	Date. 1939.	Time of Obs.	Mean Values.			Difference of Mean Values. C.T. – F.S.			Range of Extreme Values (R).						Character.
											D.			H.			
					– D.	H.	– Z.	– D.	H.	Z.	Max.	Min.	R.	Max.	Min.	R.	
	° ′	° ′		h. m.	° ′	γ	γ	° ′	γ	γ	h. m.	h. m.	′	h. m.	h. m.	γ	
Bethlehem . Cape Town .	28 18 33 57	28 24 18 28	Jan. 11 ,,	10 30 to 13 50	17 14·5 24 19·0	15377 14542	29932 29298	+ 7 04·5	– 835	+ 634							0
Bethlehem . Cape Town .			Jan. 12 ,,	06 00 to 14 00	17 18·2 24 21·1	15399 14558	29945 29296	+ 7 02·9	– 841	+ 649	12 15 13 30	07 15 08 30	24·2 18·5	06 40 06 30	10 30 11 00	45 66	0
Dundee . Cape Town .	28 08	30 17	Jan. 17 ,,	05 50 to 16 00	17 08·0 24 22·2	15078 14551	30016 29311	+ 7 14·2	– 527	+ 705	12 20 12 20	06 40 07 20	13·2 10·2	06 00 06 00	12 05 12 45	51 44	1 D
Dundee . Cape Town .			Jan. 18 ,,	06 00 to 10 00	17 08·3 24 23·1	15097 14558	30020 29313	+ 7 14·8	– 539	+ 707							1
Piet Retief . Cape Town .	27 01	30 49	Jan. 23 ,,	06 00 to 14 40	16 27·9 24 17·2	15476 14553	29913 29280	+ 7 49·3	– 923	+ 633	10 10 11 20	06 40 07 45	22·7 20·9	13 05 07 00	09 15 09 20	26 32	0
Piet Retief . Cape Town .			Jan. 24 ,,	06 00 to 16 00	16 31·0 24 22·7	15479 14563	29902 29297	+ 7 51·7	– 916	+ 605	12 35 13 00	07 35 08 30	17·9 16·0	06 20 07 00	11 20 11 30	23 43	0*
Mtubatuba . Cape Town .	28 23	32 14	Jan. 27 ,,	06 00 to 15 40	17 14·8 24 23·3	15078 14574	30013 29275	+ 7 08·5	– 504	+ 738	11 50 15 15	07 40 08 10	25·8 17·0	06 20 07 15	10 35 13 00	21 37	0*
Umbumbulu . Cape Town .	29 59	30 42	Feb. 3 ,,	06 00 to 16 00	17 58·0 24 17·7	14184 14537	30112 29296	+ 6 19·7	+ 353	+ 816	13 00 14 00	07 00 08 00	8·6 11·8	06 05 06 15	09 45 10 15	21 54	0
Umbumbulu . Cape Town .			Feb. 7 ,,	06 00 to 16 00	18 01·5 24 19·6	14150 14509	30111 29299	+ 6 18·1	+ 359	+ 812	13 00 13 15	08 20 09 00	20·7 20·4	07 05 07 20	13 15 13 15	43 48	1 D

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Greenwich Mean Time.

Field Station (F.S.) and Magnetic Observatory, Cape Town (C.T.).	Lat. S.	Long. E.	Date. 1939.	Time of Obs.	Mean Values. −D.	Mean Values. H.	Mean Values. −Z.	Difference of Mean Values. C.T. − F.S. −D.	Difference H.	Difference Z.	Range of Extreme Values (R). D. Max.	D. Min.	D. R.	H. Max.	H. Min.	H. R.	Character.
	° ′	° ′		h. m.	° ′	γ	γ	° ′	γ	γ	h. m.	h. m.	′	h. m.	h. m.	γ	
Underberg . . Cape Town . .	29 47 33 57	29 30 18 28	Feb. 16 ,,	06 00 to 16 00	19 03·2 24 22·3	14600 14542	30035 29271	+ 5 19·1	− 58	+ 764	12 35 14 04	07 00 08 51	24·2 22·0	06 40 06 51	10 20 10 15	39 48	0*
Underberg . . Cape Town . .			Feb. 17 ,,	06 00 to 15 05	19 06·1 24 19·9	14607 14545	30035 29285	+ 5 13·8	− 62	+ 750	12 48 12 48	07 30 07 33	25·7 22·6	05 58 05 58	15 05 13 33	48 52	0
Elliot . . . Cape Town . .	31 21	27 50	Feb. 28 ,,	06 00 to 16 05	20 16·2 24 23·3	14463 14533	30047 29276	+ 4 07·1	+ 70	+ 771	13 30 15 04	07 40 09 04	24·2 20·2	06 32 06 48	12 04 12 03	45 49	0*
Port St. Johns . Cape Town . .	31 38	29 33	Mar. 7 ,,	06 00 to 15 50	19 25·6 24 23·5	14088 14526	30186 29288	+ 4 57·9	+ 438	+ 898	12 45 14 03	07 46 08 48	22·2 20·7	06 20 07 48	12 04 12 18	54 56	0* Q
Gonubie Mouth . Cape Town . .	32 56	28 02	Mar. 15 ,,	06 00 to 15 48	19 46·9 24 21·5	14106 14542	29958 29279	+ 4 34·6	+ 436	+ 679	13 32 16 04	08 48 09 19	20·3 17·6	07 48 07 40	11 48 11 49	48 53	1
Gonubie Mouth . Cape Town . .			Mar. 17 ,,	06 00 to 16 00	19 46·2 24 20·9	14102 14545	29956 29289	+ 4 34·7	+ 443	+ 667	13 32 14 02	08 20 08 48	13·8 13·5	08 48 08 48	13 02 13 02	25 32	0*
Cradock . . Cape Town . .	32 10	25 38	Mar. 22 ,,	06 00 to 15 40	21 00·8 24 18·4	14390 14519	29990 29276	+ 3 17·6	+ 129	+ 714	12 48 12 48	08 17 08 17	22·0 21·6	07 18 07 18	13 48 13 48	82 80	1 D
Cradock . . Cape Town . .			Mar. 23 ,,	05 40 to 10 20	21 10·2 24 28·5	14397 14530	29986 29280	+ 3 18·3	+ 133	+ 706							1
Uitenhage . . Cape Town . .	33 47	26 23	Mar. 28 ,,	06 00 to 15 50	22 01·6 24 23·0	14078 14516	29876 29286	+ 2 21·4	+ 438	+ 590	12 48 12 47	07 20 07 30	17·5 12·4	06 48 06 48	15 50 15 50	114 106	2 D

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											D.			H.			
					– D.	H.	– Z.	– D.	H.	Z.	Max.	Min.	R.	Max.	Min.	R.	
				h. m.	° ′	γ	γ	° ′	γ	γ	h. m.	h. m.	′	h. m.	h. m.	γ	
Mossel Bay . Cape Town .	34 11′ 33 57	22 07′ 18 28	Apr. 3 ,,	06 00 to 16 00	23 14·0 24 23·9	14208 14514	29670 29277	+ 1 09·9	+ 306	+ 393	12 48 12 48	07 33 07 33	15·4 13·6	06 32 06 33	13 34 13 34	42 37	0*
Rietfontein . Cape Town .	26 45	20 02	Aug. 3 ,,	06 00 to 16 00	20 34·3 24 21·7	16043 14522	28968 29217	+ 3 47·4	– 1521	– 249	14 02 14 32	09 33 10 18	14·5 14·3	07 48 08 18	14 48 13 18	32 41	0* Q
Severn . Cape Town .	26 36	22 52	Aug. 9 ,,	06 00 to 16 00	18 01·9 24 20·9	15927 14517	29557 29218	+ 6 19·0	– 1410	+ 339	13 48 14 48	09 20 09 32	16·5 13·9	07 32 07 32	12 32 12 48	52 52	0*
Upington . Cape Town .	28 25	21 16	Aug. 16 ,,	06 00 to 16 00	20 32·3 24 20·5	15395 14473	29643 29244	+ 3 48·2	– 922	+ 399	13 48 13 48	09 48 09 48	12·0 12·5	10 02 10 17	15 48 15 58	144 122	1
Upington . Cape Town .			Aug. 17 ,,	06 00 to 11 00	20 35·9 24 24·8	15406 14484	29639 29235	+ 3 48·9	– 922	+ 404							0
Springbok . Cape Town .	29 43	17 53	Aug. 23 ,,	06 00 to 16 00	21 47·6 24 19·4	14957 14410	29293 29242	+ 2 31·8	– 547	+ 51	06 32 06 48	10 48 10 48	14·3 16·7	07 02 07 18	10 18 10 18	80 60	1 D
Springbok . Cape Town .			Aug. 24 ,,	06 00 to 11 00	21 53·9 24 24·1	15025 14483	29298 29239	+ 2 30·2	– 542	+ 59		10 03 10 17		08 55 09 02			0
Williston . Cape Town .	31 21	20 56	Sept. 4 ,,	06 00 to 16 00	22 25·7 24 20·0	14645 14488	29503 29230	+ 1 54·3	– 157	+ 273	13 44 14 18	09 00 09 48	14·0 13·0	07 20 07 32	12 10 12 18	45 54	0
Williston . Cape Town .			Sept. 5 ,,	06 00 to 11 00	22 30·5 24 25·2	14673 14513	29504 29231	+ 1 54·7	– 160	+ 273							0* Q

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											D.			H.			
					– D.	H.	– Z.	– D.	H.	Z.	Max.	Min.	R.	Max.	Min.	R.	
	° ′	° ′		h. m.	° ′	γ	γ	° ′	γ	γ	h. m.	h. m.	′	h. m.	h. m.	γ	
Windhoek . Cape Town .	22 32 33 57	17 04 18 28	Jun. 7 ,,	07 00 to 16 00	19 26·5 24 21·7	17660 14520	27807 29255	+ 4 55·2	– 3140	– 1448	14 48 14 48	09 32 09 33	9·6 11·3	08 03 08 25	13 02 13 02	43 52	0* Q
Otavi . Cape Town .	19 38	17 20	Jun. 14 ,,	06 00 to 15 50	17 38·2 24 21·0	18829 14456	27217 29268	+ 6 42·8	– 4373	– 2051	11 15 11 10	08 18 07 48	6·9 11·7	07 03 07 03	14 02 14 02	136 118	1 D
Otavi . Cape Town .			Jun. 15 ,,	06 00 to 13 00	17 38·5 24 23·3	18870 14486	27203 29252	+ 6 44·8	– 4384	– 2049	13 00 13 00	09 20 09 30	10·0 8·7	07 44 07 44	12 16 12 30	35 46	0
Swakopmund Cape Town .	22 40	14 34	Jun. 20 ,,	06 00 to 16 00	19 40·4 24 20·1	17940 14499	27388 29242	+ 4 39·7	– 3441	– 1854	06 05 05 53	09 32 09 32	7·0 9·6	08 02 07 10	13 18 13 18	53 46	0
Swakopmund Cape Town .			Jun. 21 ,,	06 00 to 10 05	19 42·7 24 20·3	17962 14511	27402 29246	+ 4 37·6	– 3451	– 1844							0
Kalkfeld Cape Town .	20 54	16 11	Jun. 24 ,,	06 00 to 16 00	19 10·8 24 22·3	18135 14506	27078 29247	+ 5 11·5	– 3629	– 2169	13 47 13 47	09 18 09 48	10·5 10·2	07 33 07 25	14 02 13 18	45 40	0*
Gobabis Cape Town .	22 27	18 59	Jul. 5 ,,	06 05 to 16 00	18 13·1 24 20·3	17405 14430	28132 29260	+ 6 07·2	– 2975	– 1128	07 48 07 55	15 32 15 32	14·2 15·4	06 05 06 05	16 01 16 05	174 152	2 D
Gobabis Cape Town .			Jul. 6 ,,	06 00 to 15 05	18 13·9 24 22·1	17471 14485	28130 29237	+ 6 08·2	– 2986	– 1107	06 04 06 32	09 48 09 48	9·2 9·2	08 17 08 47	14 17 14 02	40 25	0
Mariental Cape Town .	24 36	17 58	Jul. 14 ,,	06 20 to 15 45	20 14·3 24 17·5	16775 14519	28375 29238	+ 4 03·2	– 2256	– 863	07 48 07 48	12 33 12 33	5·7 7·6	10 02 09 48	15 47 15 47	86 75	1

* Denotes one of the TEN SELECTED QUIET DAYS. Q, an INTERNATIONAL QUIET DAY. D, an INTERNATIONAL DISTURBED DAY. – D, DECLINATION WEST. H, HORIZONTAL INTENSITY. Z, VERTICAL INTENSITY; + ve, NORTHERN; – ve, SOUTHERN HEMISPHERE.

MAGNETIC OBSERVATIONS AT THE SECULAR VARIATION FIELD STATIONS AND THE CORRESPONDING VALUES AT THE MAGNETIC OBSERVATORY, CAPE TOWN.

Magnetic Observations at the Secular Variation Field Stations and the Corresponding Values at the Magnetic Observatory, Cape Town.

Greenwich Mean Time.

Field Station (F.S.) and Magnetic Observatory, Cape Town (C.T.).	Lat. S.	Long. E.	Date. 1939.	Time of Obs.	Mean Values.			Difference of Mean Values. C.T. – F.S.			Range of Extreme Values (R).						Character.
											D.			H.			
					– D.	H.	– Z.	– D.	H.	Z.	Max.	Min.	R.	Max.	Min.	R.	
Keetmanshoop . Cape Town .	26 37′ 33 57	18 10′ 18 28	Jul. 19 ,,	h. m. 06 05 to 16 00	21 05′·4 24 20·3	γ 16149 14518	γ 28679 29221	+ 3 14′·9	γ – 1631	γ – 542	h. m. 14 02 14 18	h. m. 09 40 09 48	′ 7·9 7·8	h. m. 08 10 08 03	h. m. 14 48 14 32	γ 23 22	0
Luderitz . Cape Town .	26 39	15 10	Jul. 26 ,,	05 55 to 15 50	22 15·3 24 17·5	16389 14485	28322 29240	+ 2 02·2	– 1904	– 918	06 32 06 32	10 20 10 47	9·5 10·3	07 18 07 18	13 47 13 47	94 99	1
Luderitz . Cape Town .			Jul. 27 ,,	06 20 to 12 05	22 19·4 24 22·3	16419 14512	28337 29233	+ 2 02·9	– 1907	– 896	06 20 06 20	09 50 10 00	8·7 7·0	08 05 08 05	11 48 11 48	22 31	0
Maun . Cape Town .	19 58	23 26	Dec. 12 ,,	05 40 to 09 00	14 41·5 24 25·6	18567 14507	28234 29217	+ 9 44·1	– 4060	– 983							0
Maun . Cape Town .			Dec. 13 ,,	04 24 to 08 10	14 42·3 24 23·9	18555 14508	28232 29212	+ 9 41·6	– 4047	– 980							0*
Maun . Cape Town .			Dec. 14 ,,	05 37 to 09 13	14 43·8 24 24·7	18573 14505	28217 29215	+ 9 40·9	– 4068	– 998							0* Q
							Mean	+ 9 42·2	– 4058	– 987							
Buffels Bay . Cape Town .	34 19	18 27	1938 Mar. 25 ,,	05 30 to 16 00	24 07·3 24 27·3	14525 14592		+ 0 20·0	+ 67				13·8 14·0			44 42	0
Buffels Bay . Cape Town .			Jun. 22 ,,	06 02 to 16 00			29411 29354			+ 57							0

* Denotes one of the TEN SELECTED QUIET DAYS. Q, an INTERNATIONAL QUIET DAY. D, an INTERNATIONAL DISTURBED DAY. – D, DECLINATION WEST. H, HORIZONTAL INTENSITY. Z, VERTICAL INTENSITY: + ve, NORTHERN; – ve, SOUTHERN HEMISPHERE.

MAGNETIC OBSERVATIONS AT THE SECULAR VARIATION FIELD STATIONS AND THE CORRESPONDING VALUES AT THE MAGNETIC OBSERVATORY, CAPE TOWN.

Greenwich Mean Time.

Field Station (F.S.) and Magnetic Observatory, Cape Town (C.T.).	Lat. S.	Long. E.	Date. 1939.	Time of Obs.	Mean Values.			Difference of Mean Values. C.T. – F.S.			Range of Extreme Values (R).						Character.
											D.			H.			
					– D.	H.	– Z.	– D.	H.	Z.	Max.	Min.	R.	Max.	Min.	R.	
	° ′	° ′		h. m.	° ′	γ	γ	° ′	γ	γ	h. m.	h. m.	′	h. m.	h. m.	γ	
Van Rhynsdorp .	31 37	18 44	Aug. 29	06 00	23 15·6	14760	29092	+ 1 04·7	– 257	– 142	15 20	09 32	10·0	09 32	14 04	41	0*
Cape Town .	33 57	18 28	,,	to 16 00	24 20·3	14503	29234				15 25	09 25	9·4	09 32	14 10	40	
Van Rhynsdorp .			Aug. 30	06 02	23 16·4	14775	29100	+ 1 04·7	– 255	– 140							0*
Cape Town .			,,	to 11 02	24 21·1	14520	29240										
Van Rhynsdorp .			1940 Sept. 30	05 42	23 10·7	14673	28966	+ 1 05·0	– 259	– 165	13 18	08 19	14·6	07 49	14 18	32	0
Cape Town .			,,	to 16 10	24 15·7	14414	29131				13 18	08 35	13·4	08 03	13 48	26	
Van Rhynsdorp .			Oct. 1	05 43	23 08·9	14657	28960	+ 1 05·4	– 257	– 174	12 48	09 33	13·4	08 18	11 48	47	1
Cape Town .			,,	to 16 10	24 14·3	14400	29134				12 48	09 10	13·1	08 02	11 34	42	
Van Rhynsdorp .			Oct. 2	05 42	23 13·8	14665	28965	+ 1 04·9	– 257	– 168			13·6			40	0
Cape Town .			,,	to 12 15	24 18·7	14408	29133						14·0			42	

On 2nd October the observations were discontinued because the temperature 36·6° C. was beyond the range of the Q.M.H. thermometer. The ranges are for the period $05^h\ 42^m$ to $12^h\ 15^m$.
Total SOLAR ECLIPSE at Van Rhynsdorp on 1st October 1940 at about $14^h\ 05^m$ G.M.T.
The magnitude of the eclipse at Cape Town was 0·94.

* Denotes one of the TEN SELECTED QUIET DAYS. Q, an INTERNATIONAL QUIET DAY. D, an INTERNATIONAL DISTURBED DAY. – D, DECLINATION WEST. H, HORIZONTAL INTENSITY. Z, VERTICAL INTENSITY: + ve, NORTHERN; – ve, SOUTHERN HEMISPHERE.

THE GENUS *AUSTROSPARUS* SMITH.

By J. L. B. Smith.

(Read September 17, 1941.)

Family Sparidae.

During a revision of the Sparid fishes of South Africa (Smith, Trans. Roy. Soc. S.A., 1938, vol. xxvi, p. 241) the most difficult problem proved to be the reduction to order and uniformity of genera among the polymorphous forms generally grouped in the genus *Sparus* Linn. The views of previous workers had left the taxonomy of the species in a chaotic state, partly because of a number of intergradational difficulties. Eventually it was found (1938) that none of our species could be regarded as falling within the type genus *Sparus* Linn. Most were placed in other existing genera, while those most closely related to the Atlantic *Sparus* were grouped in a new genus, *Austrosparus*. The three species assigned to *Austrosparus* were *globiceps* Cuv., endemic, selected as the type, *sarba* Forsk., an Indian form, and *auriventris* Peters, a species previously regarded as of doubtful validity, based upon a brief and incomplete account of a Mozambique specimen. Previous workers had accepted *sarba* and *globiceps* as applying to South African specimens, the latter being a very characteristic species extending from the Cape to Natal. One of the commonest littoral and estuarine Sparids in South Africa had been identified (by previous workers) with the Indian *sarba* Forsk. During the 1938 revision it was found that among material identified (by previous workers) as *sarba*, two distinct species could be distinguished. One, common in Natal and farther north, rarely found south-west of the Kei River, was identified with *sarba* Forsk. The other, common on the south coast of Africa, and rare north of Durban, was eventually identified with the ill-defined *auriventris* Peters. The few characters mentioned in Peters's description applied to both *sarba* and the more southerly form, excepting only that *auriventris* was stated to have "On the belly each side above the ventrals a narrow golden longitudinal band" (Peters, Arch. Naturg., 1855, p. 243, translated by Fowler, 1933, U.S. Nat. Mus. Bull. 100, vol. 12, p. 179). The form found south of Natal has constantly a strong lateral golden band, whereas *sarba*, in the material I examined, had not. (Besides this difference there are others of more

weight which will be described below.) In consequence, it was decided (1938) to identify our specimens with *auriventris* Peters. Peters had assigned that species to *Diplodus* Raf., but it was obviously more closely related to *Austrosparus*.

Since that time I have been fortunate in securing together in one locality (on the coast, south of the Umtata River) a graduated series of fresh specimens of each of the forms I had (1938) identified as *sarba* and as *auriventris*. *Sarba*, when fresh, proves to have a bright golden band slightly obliquely up from the ventral base along the belly, and a faint bronze-yellow narrow line along each scale-row from the dorsal to the mid-ventral area. The other species has a strong medio-lateral golden band and only faint scale-row stripes. With this material, further study of Peters's description makes it quite clear that his *auriventris* applies to the form now identified with *sarba* Forsk., and not to the more southerly form. This latter cannot be identified with any known species, and thus becomes *Austrosparus tricuspidens* sp. n., endemic.

Genus *Austrosparus* Smith.

1938, Smith, Trans. Roy. Soc., vol. xxvi, p. 241.

Fowler (U.S. Nat. Mus., 1933, Bull. 100, vol. xii, p. 178) had made *auriventris* Peters the type of the sub-genus *Rhabdosargus* Fowler in *Diplodus* Raf. In the 1938 revision (Smith) this sub-genus had been transferred to *Austrosparus*, monotypic, with amended diagnosis. Since it is now shown that *auriventris* Peters is almost certainly a synonym of *sarba* Forsk., *Rhabdosargus* may be discarded, because *globiceps* and *sarba* do not differ by even sub-generic rank. The very characteristic features of the tricuspid teeth in juveniles and early adults of *tricuspidens* sp. n., and the scaled preopercle flange, still justify expression by at least sub-generic rank of the difference from *globiceps* and *sarba*. The new sub-genus *Prionosparus* for this form is proposed.

Key to the Species of Austrosparus.

1. (*Austrosparus*.) Preopercle flange naked. Incisors even in juveniles with entire edge.
   - A. Adult with cross-bars. Pectoral 1·1 times head. Anterior incisors chisel-edged. South coast of Africa, rare in Natal . *globiceps*.
   - B. No cross-bars in adult. Pectoral 1·3–1·4 times head. Anterior incisors lanceolate. Rare south of Natal . . . . . *sarba*.
2. (*Prionosparus*.) Preopercle flange with a few scales. Anterior incisors tricuspid in juveniles . . . . *tricuspidens*.

Sub-genus *Austrosparus* Smith.

Austrosparus globiceps (Cuvier).

1938, Smith, *loc. cit.*, p. 243.

There is nothing of importance to be added to the above description.

Austrosparus sarba (Forsk.).

1835, Ruppell, Neue Wirbel., p. 110, pl. xxviii, fig. 1.

1855, Peters, Arch. Naturg., p. 243 (*Diplodus auriventris*, Mozambique).

1861, Castlenau, Mem. Poiss. Afrique Aust., p. 25 (*Chrysophrys natalensis*).

1875, Day, Fishes India, p. 142, pl. xxxiv, fig. 6 (*Chrysophrys s.*).

1917, Gilchrist and Thompson, Ann. Durban Mus., vol. i, p. 361 (*natalensis*).

1927, Barnard, Ann. S.A. Mus., vol. xxi, p. 687 (*Sparus sarba*, part).

1933, Fowler, U.S. Nat. Mus. Bull. 100, vol. xii, p. 149 (*Sparus sarba*, part).

1934, Fowler, Proc. Ac. Nat. Sci. Phil., vol. lxxxvi, p. 470 (*bifasciatus*).

Day (*loc. cit.*) describes a species *Chrysophrys haffara* which is stated to differ from *sarba* Forsk. only in having slightly weaker anal spines and in minor variations in colour. These differences do not appear to justify distinction, since both are as a rule inconstant and of little significance. Dark shades and markings are very variable in estuarine fishes.

This Indo-Pacific form (*sarba*) appears to be widely distributed in the tropical and sub-tropical zones. I have not been able to examine a specimen from the type locality (Red Sea), but from a careful analysis of descriptions of specimens from over a wide area it would appear that the species is fairly constant, showing only little variation. Specimens from the Cape, Natal, Zululand, and Portuguese East Africa show almost no variation themselves, and all agree very closely with the diagnosis of Indian *sarba* Forsk. Apparently none of the northern and eastern specimens from the Indian Ocean were observed to have the flaring golden band on the belly (characteristic of *auriventris* Peters), but this would not have been remarked in preserved material, as the band fades rapidly after death. *Auriventris* Peters differs from the typical *sarba* (as described) only in the presence of the golden band on the belly. Preserved specimens, originally undoubtedly *auriventris*, are now indistinguishable from older material identified as *sarba*.

In the waters of Zululand and farther north, *sarba* attains a length of 500 mm. and is esteemed as a game fish. With growth the anterior

incisors thicken and shorten so as to be almost conical in large adults. They are never caniniform, nor at any stage as typically chisel-edged as those of the other species of the genus. *Sarba* has been found to extend as far south as the Bashee River; beyond that, westwards, the species is rare, but large specimens sometimes reach as far west as Mossel Bay, several generally being taken each year in the late summer at Knysna.

Sub-genus *Prionosparus* nov.

Austrosparus tricuspidens sp. nov.

1927, Barnard, Ann. S.A. Mus., vol. xxi, p. 687 (*sarba* Forsk., part).

1938, Smith, Trans. Roy. Soc. S.A., vol. xxvi, p. 247, pls. xviii, xxiii, and text-figs. 1, 7, and 8 (*auriventris*).

Types from Knysna in the Albany Museum.

This species agrees very closely in general form and structure with *A. sarba* Forsk. It may, however, clearly be distinguished at all stadia. In fresh material, *A. sarba* has the golden band along the belly originating from the ventral base; *A. tricuspidens* has a longitudinal median golden band originating above the pectoral base and running straight along the middle of the side to the caudal base. In preserved material of juveniles and adults up to 150 mm. in length the teeth are immediately diagnostic. The anterior incisiform teeth of *A. tricuspidens* are apically dilated and sharply tricuspid; those of *A. sarba* are long, slender, and pointed, but still clearly incisiform. In all stadia of preserved material the scales on the preopercle flange of *A. tricuspidens* are diagnostic. These vary in number and position, but the presence of only one is sufficient, since the preopercle flange of *A. sarba* is invariably quite naked. Also *A. sarba* has markedly longer pectorals (1·3–1·4 times head), which when folded forward extend well beyond the snout tip, while in *A. tricuspidens* the pectorals (1·1–1·2 times head) when so bent reach scarcely, if at all, beyond the snout tip. *A. globiceps* may clearly be distinguished from the other species by the absence of the golden band in all stadia. In juvenile stadia the anterior incisors of *A. globiceps* are chisel-edged and entire, and are distinguishable at a glance from the more acute shape in *A. sarba* and from the tricuspidation of *A. tricuspidens*. In *A. globiceps* the preopercle flange is naked, and dark cross-bars are present in all stadia.

A. tricuspidens is common in all tidal estuaries from the Cape Peninsula to the Kei River. It is particularly abundant in tidal rivers from Knysna to East London. Farther north it gradually diminishes in numbers, mingling with, and being progressively replaced by, *A. sarba* Forsk. *A. tricuspidens* rarely exceeds 350 mm. in length and appears to prefer estuaries to the open sea. Although small in size, its flesh is highly esteemed.

The following are the common names of the three species:—

globiceps: White stumpnose (Cape); Stumpnose (general); Go-home fish (Tzitzikama-Plettenberg area).

sarba: Silver bream (Natal).

tricuspidens: Blink-vis (Port Beaufort); Stompneus or Stumpnose (Knysna); Flatty (Eastern Province); Silvie (East London); Silver bream (Natal).

I wish to express my gratitude to the National Research Board of South Africa for financial assistance.

ALBANY MUSEUM,
GRAHAMSTOWN,
August 1941.

THE METASOMATISM OF KARROO SEDIMENTS BY DOLERITE.

(*A Paper from the University of Cape Town.*)

By Frederick Walker and Arie Poldervaart,
Geology Department, University of Cape Town.

(With Plate XIX, five Text-figures, and five Tables.)

(Read October 15, 1941.)

CONTENTS.

Introduction.

It has been known for many years, through the work of du Toit and others (3), that the Karroo dolerite magma was a very active one, capable of producing remarkable effects on the associated sediments. Recently Mountain (6) described in detail a case where a typical Karroo dolerite sill not only caused mobilisation and rheomorphic injection of feldspathic Table Mountain Sandstone, but was itself acidified by included blocks of the same material. Mountain suggested further that many of the acid veins and patches in Karroo dolerites might have a similar origin, being the product of metasomatism.

During the course of a systematic investigation of the Karroo dolerites the authors have been able to confirm this suggestion, and the present communication gives an account of three particularly good examples at Hangnest (17), Rietkop, and Alewyn's Gat.

The last case has the advantage of being exceedingly well exposed, but all three have been thought worthy of detailed study. Fourteen chemical analyses have been made in connection with the investigation and both optical and micrometric data are given as fully as possible. Unfortunately many of the products of metasomatism have undergone much contemporaneous alteration, but they retain nevertheless a very distinctive appearance in the field. Recognition of such clearly defined types in other parts of the Karroo has led the authors to believe that metasomatism of included blocks of arenaceous sediment is by no means uncommon in Karroo dolerite intrusions.

Field Characters.

Hangnest (Lat. 31° 41′ S. Long. 20° 2′ E.).

The 500-foot sill above the farmhouse of Hangnest in the Calvinia district has already been described by the authors (17) and the metasomatism of included Beaufort siltstone treated briefly.

A large block of siltstone about 50 feet in thickness is partially detached from the upper contact and forms a well-marked escarpment of which the apparent continuation is seen further down in the sill about 100 yards away, on the same strike line. The intervening rock is dolerite, but the first block is entirely surrounded by a shell of chilled basalt. Its continuation lies in dolerite by which it has been metasomatised to a granophyric rock of striking appearance in the field; long black needles of serpentinised pyroxene contrasting strongly with a pale grey matrix. No trace of unaltered siltstone was detected, but the origin of the inclusion is indicated by the occurrence of horizontal bands of different grain-size; these bands almost certainly corresponding to the original bedding of the sediment. Moreover, the division planes of the granophyric inclusion resemble those of the other block and of the overlying siltstone, but differ from those of the dolerite. Unfortunately the contact between granophyre and dolerite is nowhere visible, and the evidence is less complete at Hangnest than at the other two localities. The dolerite is a normal coarse-grained sub-ophitic type showing on outcrop great exfoliating slabs which follow the slope of the hillside. These may give place locally to small koppies formed of rectangular joint blocks.

Rietkop (Lat. 31° 52′ S. Long. 20° 19½′ E.).

About forty years ago Rogers and du Toit (8, pp. 41–42), when describing the dolerite sills of the Calvinia district, drew attention to the granophyric nature of the sill of Rietkop, near Middelpost. The sill was also referred to by du Toit (3, p. 24), who pointed out that it possesses a basic margin at

the top and suggested that it might be a composite sheet. These observers give the thickness as 250–300 feet and record a moderate or high dip.

A detailed examination by the authors showed that the best exposures occur on the N.N.E. and W.S.W. faces of the conspicuous hill Rietkop.

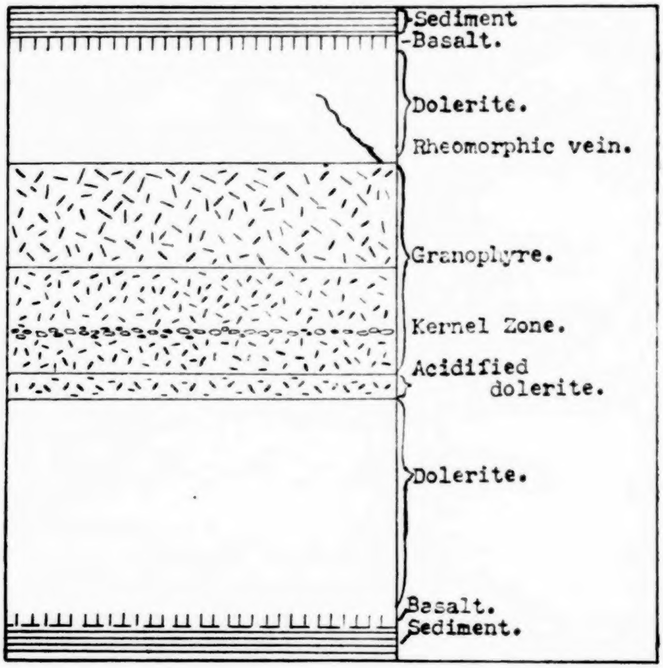

FIG. 1.—Diagrammatic section through Rietkop sill.

The inclination of the sill is very variable and it is markedly transgressive in places, but on the conspicuous granophyre escarpments the dip is low, fig. 1.

The upper contact rock is basaltic and grades into a normal medium-grained sub-ophitic dolerite, which becomes extremely decomposed and friable as the underlying granophyre is approached. On the N.N.E. face a 6-inch rheomorphic vein emerging from the granophyre traverses this decomposed dolerite. The lower contact is marked by talus, but at several places on the W.S.W. face decomposed dolerite is seen below the granophyre. On the N.N.E. face the dolerite immediately below the granophyre is fresher and the relationship between the two rocks well exposed. The

passage from granophyre to dolerite is by a series of zones which amount together to a thickness of about 8 feet. At lower levels decomposed crumbly dolerite was encountered. The estimated thickness of the sill is 200–250 feet, of which about 70 feet are granophyre.

The granophyre forms a prominent escarpment and has a close resemblance in the field to the corresponding rock from Hangnest. The division planes are similar and the stratification even more marked. On the W.S.W. face the escarpment is a double one, the two portions being separated by a long slope of debris, while on the N.N.E. face the exposures are continuous and show a sharp junction between an upper and a lower modification.

As at Hangnest the stratification is made evident by differences of grain-size, the upper portions being, on the whole, coarser than the lower.

On both faces the most striking phenomenon is a zone of conglomeratic appearance in the lower portion of the granophyre. This bed is about 12 inches thick and is continuous throughout the exposures. Close examination reveals the fact that the rounded or subangular "pebbles" consist for the most part of a grey or pink Ecca siltstone, identical to that seen a few feet above the hornfelsed shales which line the upper contact. Other "pebbles" consist of intermediate stages in the rock-series siltstone-granophyre, and many of them have a thin border of calcite. It seems clear that these "pebbles" are kernels of siltstone in a bed which proved unusally resistant to magmatic metasomatism. Some of them have undergone a limited amount of metasomatism, but most have escaped alteration. The maximum diameter recorded was about 8 inches, but 1–3 inches is about the average. They are invariably rounded to a certain extent and some are perfect spheres. A few scattered kernels are found in the granophyre below the pseudo-conglomerate stratum.

Alewyn's Gat (Lat. 32° 14′ S. Long. 22° 34′ E.).

A particularly clear example of metasomatism is seen in a road-cutting on the Beaufort West-Loxton road, about 10 miles from the former town. Blasting has recently been carried out at this locality and continuous exposures of fresh rock may be seen for a considerable distance. This cutting shows a transgressive portion of the great Bulthouders Bank sill (Schwarz, 10, p. 20). An almost vertical contact with hornfelsed shale occurs at the upper end of the exposure and dolerite is chilled here to a fine-grained basalt. The normal rock of the sill is a medium-grained ophitic olivine-dolerite. About 100 feet below this contact is a lens-shaped xenolith of Beaufort siltstone measuring about 50 feet by 8 feet (fig. 2). It is lying almost horizontally and its relations to the surrounding dolerite

are visible throughout. The central portion of the xenolith consists of a somewhat argillaceous-looking grey siltstone very similar to others in the neighbourhood. This gives place outwards to a shell of granophyre about 2 feet thick. The granophyre is of variable grain-size and very similar to those of Hangnest and Rietkop. Below the xenolith the granophyre becomes more mafic against a well-defined zone of dolerite-pegmatite,

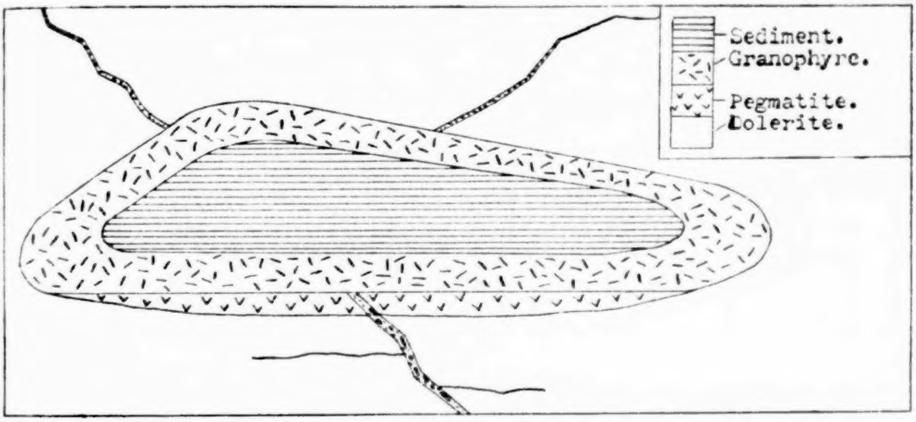

FIG. 2.—Diagrammatic section showing mode of occurrence of siltstone xenolith at Alewyn's Gat.

which in its turn shows a sharp unchilled junction against the underlying normal dolerite. The dolerite-pegmatite zone is absent above the xenolith.

Rheomorphic phenomena are conspicuous and veins of granophyric appearance pass from the granophyre into the dolerite above and below the xenolith. A 6-inch vein below the xenolith contains numerous patches of darker rock and sends off horizontal stringers. These veins do not contain the elongated crystals of pyroxene which characterise the other granophyre, but may show skeletal pseudomorphs after that mineral.

The siltstone contains sparse calcareous nodules, which in the granophyre have been converted to conspicuous spots of brownish-pink garnet.

About 100 feet below the xenolith horizontal schlieren of dolerite-pegmatite with gleaming black blades of pyroxene are seen in the normal rock. These schlieren measure up to 12 inches in thickness and show sharp unchilled junctions with the surrounding dolerite. They are coarser and fresher than the dolerite-pegmatite immediately below the granophyre.

TABLE I.

	Contact basalts.*			Dolerites.				Dolerite-Pegmatites.			Trans. Dol.	Granophyres.			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Olivine	..	..	1·6	..	..	..	1·9	..	..	..	..	..	..	..	..
Plagioclase	3·5	2·0	1·9-	47·8	48·2	44·1	46·5	31·3	38·5	32	42	14	10	11	35
Orthopyroxene	0·9	1·6	..	14·8	..	..	..	..	..	..	..	..	..	..	..
Clinopyroxene	..	0·4	1·4	29·0	42·7	42·3	43·0	27·8	30·2	23	26	27	15	14	10
Iron Ore	..	..	..	2·3	3·6	6·3	5·9	4·9	5·5	5	5	4	3	4	4
Biotite	..	..	..	0·8	2·0	0·9	0·7	1·0	1·1	1	} 3	2	2	3	3
Amphibole	..	..	..	..	..	..	..	5·8	2·8	4		..	..	..	..
Qtz. and Micro-peg.	..	..	..	5·3	6·5	6·4	2·0	29·2	21·9	35	24	53	70	68	25
Mesostasis	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
An % of plagioclase	72	72	72	68	68	68	65	50	50	51	58	35	36	36	32
Fa % of olivine	..	..	18	..	..	..	60	..	..	..	..	..	..	..	..
Fs % of orthopyroxene	17	17	..	17	..	..	..	..	..	..	..	..	..	..	..
γ of Clinopyroxene †	..	..	1·709	1·718	1·718	1·712	1·712	1·726	1·724	1·723	..	..	..	..	..
Av. length of plagioclase in mm.	..	..	..	0·8	0·9	0·4	0·4	1·5	3·0	0·8	0·6	0·7	0·6	0·5	1·0

1. Upper contact basalt, Hangnest.
2. Upper contact basalt, Rietkop, W.S.W. face.
3. Upper contact basalt, Alewyn's Gat.
4. Analysed dolerite, Hangnest (H.N. type).‡
5. Dolerite near granophyre, Hangnest (D.M. type).‡
6. Dolerite above granophyre, Rietkop, W.S.W. face (D.M. type).‡
7. Dolerite near granophyre, Alewyn's Gat (P.K. type).‡
8. Dolerite-pegmatite, Hangnest.
9. Dolerite-pegmatite 150 feet below xenolith, Alewyn's Gat.
10. Dolerite-pegmatite bordering granophyre, Alewyn's Gat.
11. Dolerite 5 feet below granophyre, Rietkop N.N.E. face.
12. Granophyre, Hangnest.
13. Upper granophyre, Rietkop W.S.W. face.
14. Lower granophyre, Rietkop W.S.W. face.
15. Granophyre, Alewyn's Gat.

* Phenocrysts. † Maximum value on cleavage fragments.
‡ Descriptions of types in Walker and Poldervaart (16).

Orthopyroxene.—Colourless.

Clinopyroxene.—$2V = 0–50°$. Pigeonitic varieties are of very pale colour and often form discontinuous cores in purplish-brown hypersthene-augite. Hypersthene-augite is generally zonal.

Olivine.—Colourless in contact basalt, pale brown in dolerite.

Contact Basalts.—The Hangnest, Rietkop, and Alewyn's Gat rocks have a dense black groundmass usually obscured by iron ore but sometimes variolitic.

Dolerites.—The Hangnest dolerite is a normal sub-ophitic rock of Downes Mountain type, dimorphous with the analysed bronzite-dolerite which occurs at a lower level. The Rietkop rock is also of this type but of finer grain. At Alewyn's Gat the dolerite is distinctly more mafic and of the markedly ophitic Perdekloof type, though the occurrence of a few discontinuous cores of early pigeonite indicates affinities with the Blaauwkrans type.

Mineralogy and Petrography.

Dolerites and Contact Basalts.

The igneous rocks responsible for the metasomatism are all normal dolerites or tholeiites belonging to types described by the authors in a previous paper (16). Their characters may therefore be condensed into a tabular summary (Table I) in which for the sake of brevity granophyres, dolerite-pegmatites, and transitional types are included.

Dolerite-Pegmatites.

These striking rocks, which are common in dolerite sheets throughout the world, consist of blades of black clinopyroxene in a variable matrix of acid labradorite, micropegmatite, quartz, ilmenite, and amphibole.

The dolerite-pegmatite of Hangnest has already been described (16, p. 140), and the rock just below the granophyre of the xenolith at Alewyn's Gat is very similar to it, except for the presence of pyrite and of sharply

defined cores of colourless pigeonite in the elongated crystals of clinopyroxene. Many of these cores have been converted to dark green serpentine; the outer portion of purplish-brown colour remaining fresh. The habit of these pyroxenes is slightly more ragged than at Hangnest and the plagioclase laths are somewhat smaller.

The dolerite-pegmatite schlieren lower down in the sill at Alewyn's Gat are considerably coarser, fresher, and richer in plagioclase. Micropegmatite, on the other hand, is less abundant. The pyroxene forming the centre of the prisms is very pale in colour, but is not discontinuous with the outer portions. The patchy distribution of the constituents is a striking feature of all three rocks and has an adverse effect on the accuracy of the modes.

Transition Dolerites.

The transition dolerites below the granophyre of Rietkop (N.N.E. face) are of very similar texture to the fresh dolerite above the granophyre. The pyroxene, plagioclase, and iron ore have the same habit, but in the transitional dolerite the elongated prisms of the first mineral have nearly all undergone conversion to yellow, green, or brown serpentine. There are, however, a few scraps of unaltered pyroxene, these being identical to the corresponding mineral of the fresh dolerite. The chief feature of the transitional dolerite, which distinguishes it from the normal rock, is the great abundance of quartz and micropegmatite. The latter constituent is of very fine grain and normal interstitial habit. Carlsbad twinning is often conspicuous in the feldspathic portion. It is evident that these transitional rocks have undergone a process of acidification and contemporaneous decomposition which became progressively intense towards the granophyre.

Granophyres.

The granophyre of Hangnest has been described and figured by the authors (16, p. 140, pl. viii, fig. 3), and the corresponding rocks of Rietkop and Alewyn's Gat present the same features under the microscope, viz. conspicuous ragged prisms of clinopyroxene embedded in a matrix of plagioclase laths, quartz, and micropegmatite. Biotite, iron ore with rod-like habit, and sphene are the most conspicuous accessories. The rocks have all undergone considerable decomposition, the clinopyroxene being almost invariably completely altered to yellowish-green or brown serpentine, while the plagioclase is generally turbid. There has been a good deal of silicification, and quartz often occurs as large interstitial patches in addition to relict grains and graphic inclusions. This mineral is most prominent at Hangnest and least abundant at Alewyn's Gat and there is a comple-

mentary variation in the proportion of feldspar. This is in accordance with the composition of the original sediments.

The stratum at Rietkop with kernels of relatively unaltered siltstone is of interest. A fine-grained granophyre forms the matrix in which the kernels lie. The kernels themselves mostly consist of a fine-grained arenaceous sediment with angular grains of detrital quartz averaging about 0·1 mm. in diameter. This is distinctly coarser than the normal siltstone, which the kernels otherwise resemble. It is possible that this coarseness of grain has hindered reaction, resulting in the preservation of relict kernels. Some of the kernels show a progressive transition outwards by a series of well-defined zones to the granophyric matrix, while others have a narrow margin of calcite. In the last type calcite is also present as a cement in the kernels.

A thin section was made of a peculiar calcareous kernel from this stratum (N.N.E. face). In the centre there is a core of coarsely crystalline quartz and alkali feldspar, with smaller crystals of granular diopside and sphene, calcite and biotite as accessories. This gives place outwards to more normal material and finally to a granophyre unusually rich in biotite. We seem here to be dealing with a small calcareous nodule in the sediment.

It has been mentioned already that the siltstone of Alewyn's Gat is of the nodular type and that the concretions are calcareous. The metasomatism of these nodules leads to striking effects under the microscope, though sections are exceptionally difficult to prepare. A reddish-brown isotropic garnet ($n = 1{\cdot}860 \mp 0{\cdot}005$) is the chief constituent of these nodules in the granophyre and forms perfect dodecahedra. The garnet is surrounded by a zone in which quartz is absent and feldspar scarce, the place of these minerals being taken by fibrous pectolite and what appears to be turbid thomsonite. In this zone the pyroxene of the rock is in good preservation and seems to be hypersthene-augite. It sometimes encloses discontinuous cores of pigeonite which are generally serpentinised, but the most striking feature is the occurrence of margins of green soda-pyroxene. This pyroxene has the characteristic yellow-green pleochroism of aegirine-augite.

Similar cases of the preservation of pyroxene in calcareous zones have been noticed at Rietkop, and here again the crystals show cores of pigeonite surrounded by hypersthene-augite. In one case it was found possible to determine γ of the hypersthene-augite, the value found being 1·728, indicating a variety rich in iron. The alkali feldspar is generally too much decomposed to be measured accurately, but β in one case (Rietkop) was found to be 1·526 with 2V large.

Sediments.

The sediments call for little description. They are all very fine-grained argillaceous sandstones or siltstones, the average grain-size usually being well below 0·1 mm. Besides angular grains of clastic quartz, others of turbid plagioclase or potash feldspar are common and together with the quartz are set in an obscure argillaceous matrix containing sericite, biotite, chlorite, serpentine, and irregular grains of magnetite. Apatite needles, presumably of magmatic introduction, may sometimes be detected.

The accessory minerals found in the heavy residue include sphene, colourless or pale pink garnet, zircon, and tourmaline. The purest sediment is found at Rietkop, and the most argillaceous at Alewyn's Gat.

Rheomorphic Veins.

The rheomorphic veins issuing from the sedimentary inclusion of Alewyn's Gat are sufficiently fresh for microscopic examination. Those occurring above the xenolith resemble the granophyre shell and need not be described, but the 6-inch vein passing downwards presents some peculiar features. The lighter patches consist of euhedral laths of turbid plagioclase in an abundant matrix of micropegmatite, the sparse accessories being biotite, serpentine (probably after clinopyroxene), and magnetite. Many of the dark patches have, however, a strong resemblance to the dolerite-pegmatite immediately below the granophyre. The pyroxene and plagioclase have the same habit and optical properties as in the dolerite-pegmatite, and there is the same abundant development of amphibole and biotite. There is also well-marked graphic intergrowth of plagioclase with clinopyroxene. Occasionally patches with ophitic clinopyroxene similar to that of the normal dolerite are seen, and some of the larger of these consist of normal dolerite throughout.

PETROLOGY.

It will be conceded, the authors hope, that in all three cases the granophyric rocks described above are due to the alteration of siltstone by dolerite. This alteration appears to be of a metasomatic nature involving a certain amount of magmatic addition, and will be discussed below.

The Evidence for Metasomatism.

The authors believe that the granophyres have in all three cases been produced by a metasomatic process, but the evidence for this is strongest at Rietkop. It may be demonstrated there that the granophyric rock was formed with the minimum of disturbance, for the resistant stratum containing the kernels of unaltered siltstone keeps rigidly to the same

position over a wide area showing, moreover, no signs whatever of movement, or contortion. The margins of the kernels and of the surrounding zones are clear-cut, which is a characteristic phenomenon in pyro-metasomatism (Reynolds, 7, p. 403). Well-defined zones are also to be seen round the siltstone zenolith at Alewyn's Gat and in the acidified dolerite below the granophyre on the N.N.E. face of Rietkop. It seems, then, that the process of alteration has been a molecular one, but there is evidence that the siltstone was rendered plastic by heat and by the introduction of magmatic material. The pyroxene pseudomorphs as well as the few fresh pyroxene crystals in the granophyre have a habit identical to that of the same mineral in the volatile-rich portions of the adjacent dolerite. They show no signs of sieve texture though detrital quartz grains are abundant, and it is probable that they grew in a medium comparable in viscosity to the crystallising dolerite. They were in short able to push aside the adjacent crystals which tended to hamper their growth.

Furthermore, at the two localities where the margins of the granophyre are exposed, rheomorphic veins are seen to issue from the xenolith, showing that they were reduced finally to such a plastic state that they assumed magmatic properties.

Mountain (6) has described in detail syntectic phenomena caused by the intrusion of a sheet of typical Karroo olivine-dolerite into Table Mountain Sandstone at Coedmore Quarries, near Durban. The dolerite is very similar to that of Alewyn's Gat, but the T.M.S. is coarser and more quartzose than the Beaufort siltstone, with the consequence that the reaction phenomena are somewhat different. At Coedmore the syntectic phenomena have been brought about by a much more intimate mingling of sediment and magma. Variation from dolerite to T.M.S. is continuous and not as a series of zones, and the very distinctive granophyres of the Karroo localities are absent. One point of resemblance, however, is the marked decomposition associated with the reactions. It is believed that this is a contemporaneous hydrothermal process due to the high water-content of the included sediment.

One of the most interesting features in the formation of the metasomatic granophyres is the curious mineral transformation brought about in the neighbourhood of the small calcareous pellets in the Alewyn's Gat inclusion. It would seem that there was insufficient silica in the centres of the nodules to form the grossular garnet which is now their chief representative in the granophyre, and that silica had therefore to be obtained from the adjacent material. The latter was thus subjected to a process of desilication with a resultant concentration of alkalies and the formation of pectolite, thomsonite, and aegirine-augite. It seems clear that molecular diffusion took place with comparative freedom.

Rheomorphic and Other Associated Phenomena.

The rheomorphic veins issuing from the xenolith at Alewyn's Gat are of interest. Those from the upper side consist of typical fine-grained metasomatic granophyre and represent a stage when the granophyric shell of the xenolith had developed just sufficient mobility to be capable of rheomorphic injection. They are quite free from inclusions of the surrounding rock and may have been intruded while the latter was not completely crystalline.

It is suggested that the vein passing downwards from the lower side of the xenolith may belong to a later stage. It consists of considerably more felsic material and is comparatively free from the pyroxene prisms which characterise the normal metasomatic granophyre. Possibly it represents residual liquid developed in the pore spaces of the granophyre and squeezed out as rheomorphic magma during the last stages of crystallisation. The adjacent dolerite-pegmatite and dolerite were clearly solid at the time of injection, and fragments of both types were broken or stoped off the sides of the vein (Pl. XIX, fig. 1). The rheomorphic magma retained insufficient energy to react with them with any freedom and they are largely unaltered.

A somewhat similar phenomenon is seen at Hangnest, where the partly detached block of siltstone sends off rheomorphic material which traverses and brecciates the surrounding shell of chilled basalt. In both cases the injection was accomplished with sufficient force to break up solid rock, but in neither case had the rheomorphic material sufficient energy to react with the fragments to any extent.

The question of the origin of the dolerite-pegmatite zones and schlieren is postponed till the next section, since it is largely a chemical one.

Chemistry.

Fourteen chemical analyses were made by Mr. F. Herdsman in order to throw some light on the processes described above, and they are given in Table II, together with the norms.

Metasomatic Processes.

The chief points brought out by the analyses can be seen by inspection of the table, but they are emphasized when the oxides are plotted on ordinary variation diagrams with silica on the abscissa and the other oxides on the ordinate. A separate diagram has been made for each locality, and this form of plotting seems to yield more information than any of the triangular diagrams used successfully in other investigations, figs. 3–5.

By joining the points representing siltstone, granophyre, and basalt

TABLE II.

Analyses.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
SiO_2	70·86	69·26	64·52	69·97	66·24	65·14	59·44	57·36	56·16	52·68	53·38	52·52	53·03	51·78
TiO_2	0·68	0·38	0·76	0·59	0·69	0·46	0·92	1·17	1·94	1·97	1·18	1·14	1·06	0·92
Al_2O_3	13·48	14·82	16·66	13·69	14·26	14·92	15·76	14·38	13·08	13·12	15·64	16·03	14·90	15·34
Fe_2O_3	0·12	0·81	2·23	0·13	0·94	1·18	4·11	2·54	3·52	2·14	0·23	0·37	0·98	1·07
FeO	3·31	3·89	3·44	3·82	4·48	5·04	3·44	8·23	10·29	10·62	10·76	9·12	8·85	10·58
MnO	0·03	0·12	nil	0·03	0·04	0·04	0·08	0·13	0·20	0·23	0·25	0·08	0·13	0·22
MgO	1·52	1·88	1·75	1·52	2·22	2·17	3·56	3·17	2·22	5·13	5·67	5·14	7·32	6·44
CaO	2·34	1·29	1·24	2·02	1·60	2·49	5·64	7·18	6·63	9·44	9·36	8·89	9·40	9·88
Na_2O	3·07	1·78	2·87	3·83	2·61	2·70	2·48	1·96	2·26	2·68	1·72	2·01	2·02	2·54
K_2O	2·06	3·42	3·54	2·97	3·88	3·38	1·90	1·54	1·94	0·89	0·95	0·82	0·72	0·66
H_2O +	2·08	2·23	2·82	1·34	2·38	1·96	2·75	1·08	1·33	0·97	0·36	1·98	0·74	0·63
H_2O −	0·08	0·22	0·06	0·13	0·49	0·39	nil	0·58	0·08	0·08	0·12	0·80	0·35	nil
P_2O_5	0·14	0·16	0·06	0·09	0·12	0·20	0·14	0·31	0·44	0·22	0·16	0·21	0·19	0·14
CO_2	tr.	..	nil	..	tr.	tr.	nil	0·14	nil	nil	nil	0·66	0·20	nil
Total	99·77	100·07	99·95	100·18	99·95	100·14	100·17	99·77	100·09	100·17	99·78	99·77	99·89	100·20

Norms.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
Q.	35·7	38·1	27·9	27·6	27·0	24·8	20·2	17·7	15·8	4·5	6·1	8·0	5·5	0·3
Or.	12·6	20·0	20·6	17·8	22·8	20·0	11·1	8·9	11·1	5·6	6·1	5·0	3·9	3·9
Ab.	26·2	15·2	24·6	32·0	22·0	23·0	21·0	16·8	18·9	23·1	14·2	16·8	16·2	21·5
An.	10·8	5·6	5·3	9·2	7·2	11·7	26·4	25·9	20·0	20·6	32·0	32·2	29·8	28·4
Cor.	2·1	6·1	6·2	0·8	3·4	2·4	..	..	..	..	..	..	..	..
Di. Wo.	..	..	..	..	..	..	0·4	3·3	4·3	10·6	5·8	2·8	6·4	8·4
Di. En.	..	..	..	..	..	..	0·3	1·4	1·3	4·9	2·6	1·3	3·5	4·0
Di. Fs.	..	..	..	..	..	..	0·0	1·8	3·2	5·5	3·2	1·5	2·6	2·2
Hy. En.	3·8	4·7	4·4	3·8	5·6	5·3	8·6	6·5	4·2	7·9	11·7	11·5	14·8	12·1
Hy. Fs.	4·8	5·8	3·2	5·8	6·3	7·4	1·5	9·2	10·0	9·2	14·9	13·1	11·4	13·3
Il.	1·4	0·8	1·5	1·2	1·4	0·9	1·7	2·1	3·7	3·8	2·3	2·1	2·1	1·5
Mt.	0·2	1·2	3·3	0·2	1·4	1·9	6·0	3·7	5·1	3·0	0·2	0·9	1·4	1·6
Ap.	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·7	1·2	0·3	6·3	0·3	0·3	0·3
Cc.	..	..	..	..	..	..	..	0·2	..	..	..	1·6	0·5	..
H_2O	2·2	2·5	2·7	1·5	2·9	2·4	2·8	1·7	1·4	1·1	0·5	2·8	1·1	0·6

1. Siltstone above upper contact, Rietkop (W.S.W. face).
2. Siltstone above upper contact, Hangnest.
3. Siltstone centre of xenolith, Alewyn's Gat.
4. Granophyre, fine-grained transitional type, Rietkop (W.S.W. face).
5. Granophyre, upper coarse rock, Rietkop (W.S.W. face).
6. Granophyre, Hangnest.
7. Granophyre, upper border of xenolith, Alewyn's Gat.
8. Dolerite-pegmatite, centre of sill, Hangnest.
9. Dolerite-pegmatite, immediately below xenolith, Alewyn's Gat.
10. Dolerite-pegmatite 150 feet below xenolith, Alewyn's Gat.
11. Basalt, upper contact, Rietkop (W.S.W. face).
12. Basalt, upper contact, Hangnest.
13. Dolerite, normal bronzite-bearing type, Hangnest.
14. Olivine-dolerite below xenolith, Alewyn's Gat.

(or dolerite) and neglecting, for the moment, the various dolerite-pegmatites, it is seen clearly that:

(*a*) Metasomatism of the siltstone to granophyre involves in all three cases reduction of silica and increase in the total iron oxides and magnesia, the variation of the last two constituents being almost linear.

(*b*) The variation of the other oxides is irregular, following no definite rule.

The marked non-linear variation of some of the oxides precludes the possibility of the granophyres originating by simple mixture of dolerite and siltstone, quite apart from the other evidence against this hypothesis.

Although the variation of some of the oxides is irregular, this is only to be expected in metasomatic processes. As Dr. Reynolds (7, p. 398) has put it in her very careful study of the Colonsay example, "The circumstances which contributed towards the present distribution and relative concentration of the elements in the transfused xenoliths include: (*a*) sequence of introduction into the xenoliths; (*b*) relative rate or power of diffusion through the xenoliths; (*c*) sequence (in both time and space) of fixation by the xenoliths." The sediments, too, varied in their permeability by the metasomatic agents, and it is scarcely surprising that with so many factors operating the variation of the oxides is irregular. Unfortunately the present examples are less simple than those of Colonsay, where the end-points are hornblendite and a rock containing 93 per cent. of normative quartz. In all cases the original siltstone was not far removed in chemical composition from a normal acid or sub-acid igneous rock, as may be seen by inspection of the norms. Thus all the bases are fully represented at the acid end-point. One thing, however, is fairly clear. The magmatic addition was relatively slight, and magnesia and iron oxides were among the most readily diffusible constituents. They combined with silica to

form the conspicuous prisms of pyroxene which characterise the coarser granophyres. The proportion of pyroxene varies according to the composition of the original sediment, but in the fully metasomatised granophyres the crystals are of quite definite habit and probably of definite

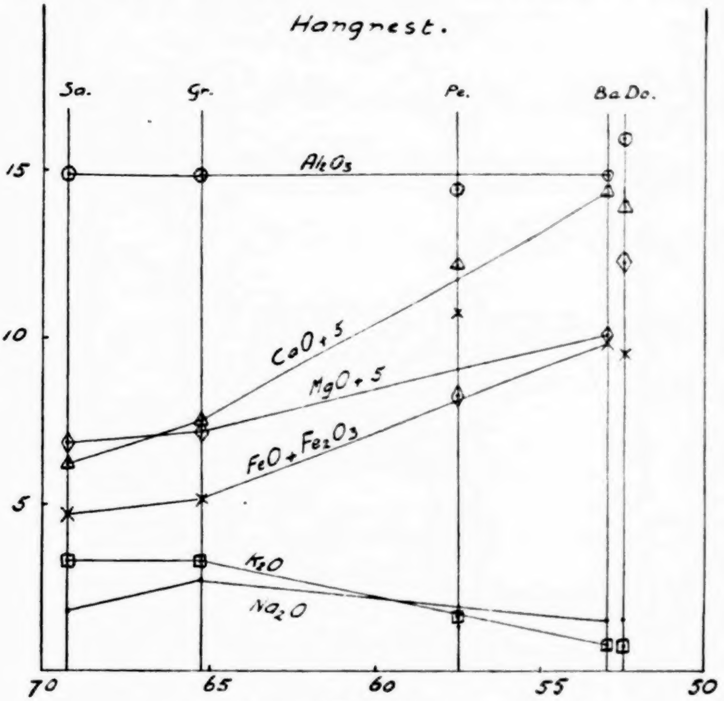

FIG. 3.

composition. The matrix, on the other hand, is very variable in its make-up, but, since most of the minerals are felsic and somewhat ill-defined, this is not visible in the hand specimen.

The following suggestion is offered to account for one of the major abnormalities in the variation, viz. the high CaO content of the granophyre of Alewyn's Gat. The siltstone is the most aluminous of the three, showing 6·1 per cent. of corundum in the norm, and it is thought that this surplus alumina may have had an affinity for the abundant lime of the dolerite, the formation of anorthite being thereby stimulated. An alternative explanation is that most of the lime in the xenolith is concentrated in nodules and that one of these occurred inside the specimen submitted for

analysis. The CaO percentage of the siltstone is certainly very low. It may be stated at this point that no adequate explanation can be offered for the occurrence of the calcite margins round some of the unaltered kernels

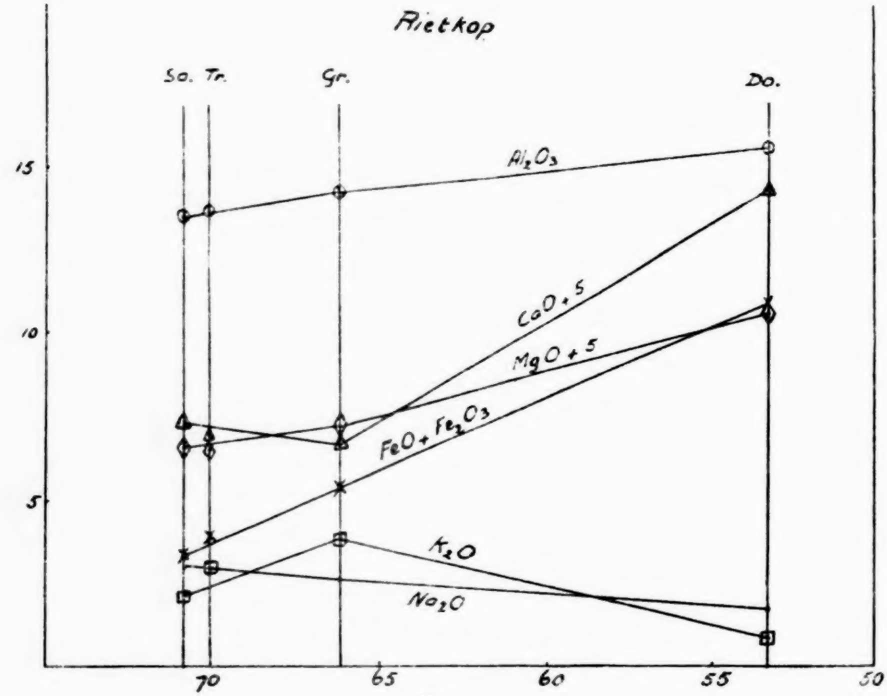

FIG. 4.

in the Rietkop granophyre, though it is possible that they were formed during some late hydrothermal process.

The mechanism of the metasomatic processes under discussion is admittedly obscure, but there seems proof that there was flow of the following elements from the dolerite into the sediment to form the granophyre. They are given below in order of decreasing diffusibility.

Rietkop.	Hangnest.	Alewyn's Gat.
K	Ca	Ca
Fe	Fe	Fe
Mg	Mg	Mg
Al		

There was, on the other hand, an equally definite flow of certain other constituents from the sediment into the adjacent igneous rock, but this will be considered in the next section.

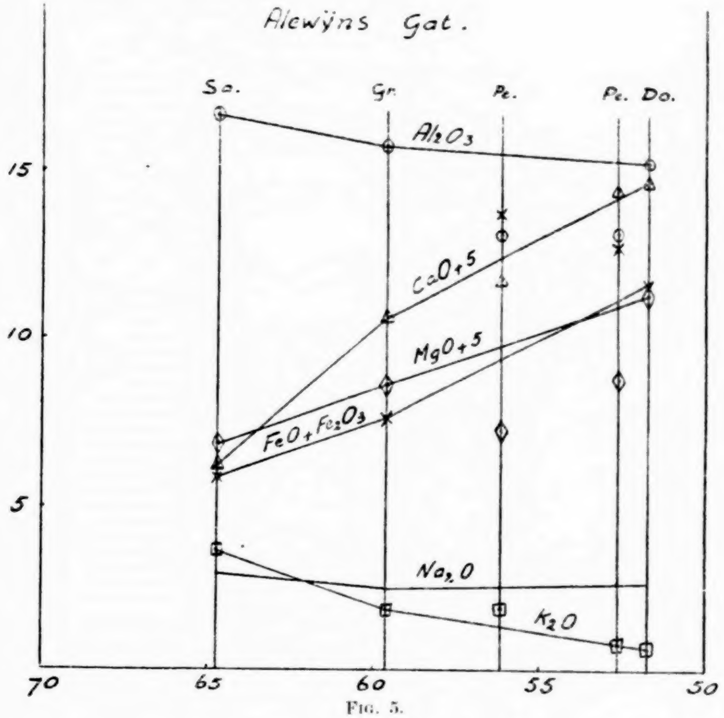

FIG. 5.

Origin of the Dolerite-Pegmatites and Acidified Dolerites.

All the dolerites or dolerite-pegmatites adjacent to the granophyres seem to be somewhat more acid than normal, and in the case of the former there has been undoubted acidification. The dolerite below the granophyre on the N.N.E. face of Rietkop, for instance, is considerably richer in micropegmatite and poorer in mafic minerals than the normal dolerite, indicating a transference of silica and alkalies from the sediment. Again the transference seems to have been a metasomatic one, for there are no signs of magmatic penetration, and contacts between granophyre and dolerite and between zones in the dolerite are quite sharp.

The dolerite-pegmatites of Hangnest and Alewyn's Gat present a more difficult problem. The schlieren about 150 feet below the xenolith at

Alewyn's Gat are, however, almost certainly the product of normal crystal fractionation, for their chemical composition bears a relationship to that of the normal dolerite, which is in keeping with other examples of similar magma-type from Great Britain and America. In those examples the magma was demonstrably inert and the possibility of syntexis or metasomatism may be ruled out. The following table brings out the closeness of the resemblance:—

TABLE III.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	Na_2O.	K_2O.
1.	51·78	15·34	1·07	10·58	6·44	9·88	2·54	0·66
2.	52·68	13·12	2·14	10·62	5·13	9·44	2·68	0·89
3.	51·46	16·24	3·04	9·58	3·47	8·38	3·01	0·87
4.	52·50	18·28	1·97	7·61	2·58	9·34	3·78	1·03
5.	50·51	14·61	3·50	8·85	5·32	8·76	2·55	1·19
6.	49·70	15·64	2·42	11·35	3·06	8·03	2·90	1·22
7.	51·56	13·81	0·96	11·32	7·40	10·08	2·08	0·96
8.	52·94	14·80	0·16	12·00	5·42	8·32	1·98	1·50

1. Dolerite, Alewyn's Gat.
2. Dolerite-pegmatite 150 feet below xenolith, Alewyn's Gat.
3. Diabase, Palisades (Walker, 15, p. 1095).
4. Diabase-pegmatite, Palisades, *ibid.*
5. Dolerite (average), Whin Sill (Tomkeieff, 13, p. 1064).
6. Dolerite-pegmatite, Whin Sill, *ibid.*
7. Diabase, Goose Greek, Va. (Shannon, 11, p. 13).
8. Diabase-pegmatite, Goose Greek, Va., *ibid.*

The difficulties arise when we consider the dolerite-pegmatite immediately below the xenolith at Alewyn's Gat. A search amongst the analyses of tholeiitic magmas which are demonstrably inert has revealed only two which are at all comparable. They are quoted below together with those of the Hangnest pegmatite and of the rock under discussion.

TABLE IV.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	Na_2O.	K_2O.
1.	56·16	13·08	3·52	10·29	2·22	6·63	2·26	1·94
2.	57·36	14·38	2·54	8·23	3·17	7·18	1·96	1·54
3.	56·22	16·33*	3·11	7·94	2·99	5·63	3·84	1·65
4.	56·15	14·78	3·88	5·65	2·83	5·00	2·47	2·22

* Includes TiO_2 and P_2O_5.

1. Dolerite-pegmatite below xenolith, Alewyn's Gat.
2. Dolerite-pegmatite, Hangnest.
3. Dolerite, Carribber, Central Scotland (Falconer, 4, p. 148).
4. Dolerite-aplite, Snook Point, Whin Sill (Smythe, 12, p. 45).

The two British rocks are distinctly more alkaline than the S. African, and they have a different appearance and paragenesis. They seem to be the result of mingling of normal dolerite with an acid rest-differentiate, and, when their analyses are plotted on a silica variation diagram with those of the normal rocks, an approximation to straight line variation is found in both cases. The exceedingly capricious distribution of micropegmatite in the Scottish sill is noteworthy. When normal crystal fractionation is carried a stage further than in Table III, the product seems to be somewhat different, as is shown by the following two analyses of extreme differentiates of the Palisades magma. They may be compared with analyses 3 and 4 of Table III, and the analysis of the undifferentiated magma as represented by the chilled basaltic contact.

TABLE V.

	SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	Na_2O.	K_2O.
1.	60·55	11·88	3·22	10·21	0·85	4·76	4·04	2·10
2.	51·34	12·71	2·65	14·14	3·66	7·44	2·43	1·44
3.	51·88	14·53	1·35	9·14	7·78	9·98	2·06	0·93

1. Quartz-diabase, Palisades (Lewis, 5, p. 122).
2. Quartz-diabase, Palisades, *ibid.*
3. Basaltic diabase, lower contact of Palisades, *ibid.*

It seems, then, that even in cases where syntexis or metasomatism may be ruled out, differentiation is complex and may follow widely diverging courses, and the value of information gained by comparing analyses must be speculative.

In the authors' opinion the dolerite-pegmatite below the Alewyn's Gat xenolith is primarily the product of crystallisation differentiation, for its mineralogy and moderate iron enrichment are in keeping with that mode of origin.

It has been emphasized by Alling, however (1, pp. 247–248), that the development of pegmatitic phases is stimulated by assimilation, and cases have been described where these pegmatites are the only suggestion of assimilation. A recently described example is provided by the Skaergaard intrusion of E. Greenland. Wager and Deer (14, p. 190) have described how

blocks of granophyre in the upper parts of the mass have formed pegmatitic hybrids of quartz-gabbro with the basic igneous rock.

The authors' reasons for favouring origin by crystallisation differentiation are: first, the complete absence of the pegmatitic phase above the xenolith; and, second, the enrichment in iron of the dolerite-pegmatite. It has been shown that iron passed into the xenolith from the surrounding magma, and one might have expected the same relative poverty of that constituent in the dolerite-pegmatite which one sees in the dolerite below the granophyre at Rietkop (N.N.E. face).

Its absence points to formation of the dolerite-pegmatite after the metasomatic process had been completed. The acidification of the surrounding dolerite seems to have been less thorough at Alewyn's Gat than at Rietkop, but it will be recalled that the siltstone of Rietkop is much more quartzose than that of Alewyn's Gat and forms, moreover, no less than one third of the total thickness of the sill.

There can be little doubt that the formation of the dolerite-pegmatite was favoured by the presence of distillates from the xenolith, and it is also possible that some of the quartz in the pegmatite is due to hydrothermal replacement.

The origin of the dolerite-pegmatite of Hangnest is still more obscure. Again its composition is in keeping with an origin through mild crystal fractionation, but the possibility of incorporation of sediment cannot be excluded. The authors have shown that sedimentary material has been incorporated in this intrusion, and it is perhaps significant that the pegmatitic patches lie below the centre of the sill and near the end of a block of sediment which was raised up from the lower contact.

No further information is yielded by including the analyses of the dolerite-pegmatites in the variation diagrams. The points are too few for curves to be drawn with any confidence and their inclusion upsets the linear variation of the total iron oxides and of MgO.

Lastly, it will be noted that the metasomatic processes and development of pegmatite phases go on equally readily in dolerites with orthopyroxene and dolerites with olivine. The two types are indeed quite near to one another in chemical composition, the olivine-bearing rocks being slightly the more femic.

Application of Results.

The three examples described in the present communication show that the Karroo dolerite magma reacted readily with the fine-grained siltstone of Ecca and Beaufort age and that the product is a highly distinctive type of metasomatic granophyre which may be easily recognised in the field.

This type seems to have a widespread distribution in the Karroo and includes many rocks referred to as granophyre or diorite in earlier accounts.

For instance, some of the acid material capping the Bloemfontein-Kuilwater sill in the Calvinia district and the great sill of the Andriesberg near Sterkstroom is identical to the coarser granophyres of Rietkop and Alewyn's Gat, and may thus be regarded as of metasomatic origin.

In the course of a fairly comprehensive survey of Karroo dolerite sills from Calvinia to Umhlali in Natal very few acid modifications were encountered for which a metasomatic or syntectic origin was not at least possible. Schöltz, for instance (9, p. 96), when referring to the acid roof zone of the Ingeli mass, does not exclude the possibility of assimilation or syntexis and comments upon the presence of 3–5 per cent. of corundum in the norms.

When the sedimentary material involved is not of the argillaceous siltstone type, the product differs markedly from the granophyres described above. For example, the syntectic rocks of Coedmore Quarries are of entirely different appearance, as are the syntectic shells surrounding small fragments of Ecca sandstones caught up in the series of thin sills exposed on Sheffield Beach, Umhlali. The chief difference is the absence of elongated pyroxene prisms, but in some cases the sediment at the contact suffered what appears to be pure melting, though one must also reckon with the possibility of some transfusion (du Toit, 2, pp. 186–187). Rheomorphic phenomena are a very common accompaniment of syntexis or metasomatism. There is, in fact, sufficient evidence available to show that the Karroo dolerite magma was quite abnormally active in its behaviour towards the associated arenaceous sediments, and, considering the greater opportunities for reaction at lower levels, the poverty of individual intrusions of acid or even sub-acid types amongst the Karroo suite is a little surprising. It may well be, however, that the acid reaction products were, like the products of crystal accumulation, only just capable of movement and without the energy to ascend to higher levels in the crust.

General Conclusions.

1. The Karroo dolerite magma is capable of converting argillaceous siltstone to a distinctive type of granophyre, characterised by conspicuous pyroxene prisms, and such rocks are of widespread distribution.

2. The conversion to granophyre is brought about by a metasomatic process in which magmatic addition—mainly of cafemic oxides—has been comparatively slight.

3. Rheomorphic phenomena are associated with the later stages of the process, proving that the granophyric rock became fully mobilised.

4. There was a metasomatic transfer of acid material from the granophyre to the dolerite in some cases, and in others a tendency to develop late dolerite-pegmatite at the contact between granophyre and dolerite.

5. The metasomatic processes were associated with marked contemporaneous decomposition.

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EXPLANATION OF PLATE.

Fig. 1. Rheomorphic vein below xenolith at Alewyn's Gat, showing dark included fragments of dolerite and dolerite-pegmatite. × ⅓ natural size.

Fig. 2. Granophyre from kernel zone, W.S.W. face of Rietkop. Spherical and subangular kernels of siltstone and fine-grained granophyre are embedded in granophyre of slightly coarser grains. Many of the kernels show thin margins of calcite. The dark patch shows the appearance of a weathered surface. × ⅔ natural size.

Fig. 3. Photomicrograph of medium-grained granophyre, Hangnest. Conspicuous pseudomorphs in serpentine after clinopyroxene are set in a turbid matrix of quartz, micropegmatite, and andesine. × 10·5 diameters. Ordinary light.

Fig. 4. Granophyre from xenolith, Alewyn's Gat. A coarse modification showing conspicuous prisms of serpentinised pyroxene. × ⅔ natural size.

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Fig. 1.

Fig. 2.

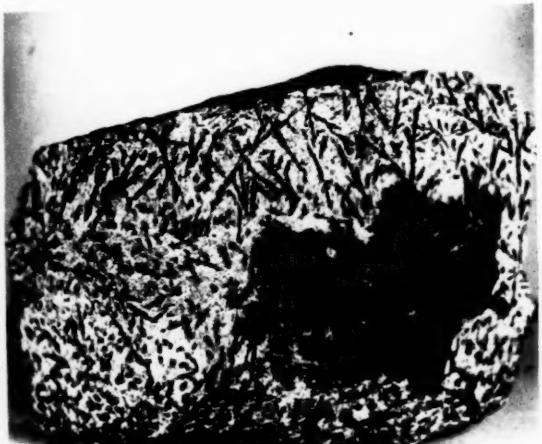

Fig. 3.

Fig. 4.

Frederick Walker and Arie Poldervaart.

Neill & Co., Ltd.

THE KINETICS OF THE OXIDATION OF ORGANIC COMPOUNDS BY POTASSIUM PERMANGANATE (1).

PART IV: SODIUM FORMATE IN AQUEOUS SOLUTION.

By L. M. HILL and F. C. TOMPKINS.

(With two Graphs and four Tables.)

(Read November 19, 1941.)

The kinetics of oxidation of formates is of importance because formic acid frequently appears as an intermediate oxidation product in the reactions of the more complex aliphatic acids with potassium permanganate. Errors associated with attempts to oxidise quantitatively such acids as tartaric, malonic, citric, maleic, fumaric, etc. (2), are largely due to the lack of information about the conditions necessary either (*a*) entirely to prevent the oxidation of the formic acid produced, or (*b*) completely to oxidise this to carbon dioxide. Furthermore, a knowledge of the mechanism operative in the oxidation of this acid is a necessary preliminary to a proper understanding of the processes taking place during the oxidation of more complex acids.

The kinetics of the permanganate/formic acid reaction has been previously studied by Holluta (3), and more recently by Mann and Tompkins (4). The conclusions of these workers agree in that (*a*) the formate ion, and not the undissociated formic acid molecule, is responsible for the reduction of the permanganate, and (*b*) the reaction is kinetically of the second order. Since the formate ion is the reductant, it would be expected that the same mechanism would be operative for the oxidation of formic acid and of its sodium salt. Nevertheless Holluta (3) and (5) has proposed two different processes. In Part III of this series (4), an alternative mechanism, which is also applicable to the sodium formate oxidation, was advanced. The study of this latter, now being reported, permits of an unambiguous decision between these two views.

EXPERIMENTAL.

All reagents, which were of A.R. quality, were dried before use. The permanganate solution was filtered through glass wool and standardised

daily against arsenious oxide (6). The strength of the formate solutions was determined by adding an excess of standard permanganate solution to known volumes of the former, buffered with sodium carbonate. At 30° C. the reaction was complete in ten minutes and then the solution was acidified, treated with potassium iodide, and titrated with N/100 thiosulphate solution. The method is preferable to that of Vogel (7) since this latter has been shown to be subject to error (4). Because of the instability at this dilution, the thiosulphate solution was standardised twice daily, using potassium iodide and N/100 potassium dichromate solution. Since the liberation of iodine in such dilute solutions is slow, the reaction was allowed to proceed in the dark for 15 minutes before titration, a blank being performed to correct for any photochemical oxidation of the hydriodic acid.

The progress of the oxidation was followed by the iodometric method used in Part I (8), the reaction being stopped at measured intervals of time by the addition of an excess of acidified potassium iodide solution. The loss of oxidising power of the permanganate was calculated from the amount of iodine liberated. All experiments were conducted in a thermostat, the temperature variation of which was less than 0·02° C., the reaction mixture being stirred electrically throughout the course of the oxidation. Since hydrated manganese dioxide is precipitated, the method of withdrawal of aliquots might be inaccurate on account of the adherence to the glass of this. The precipitate was therefore produced in the form of a colloidal sol by using low concentrations of reactants with rapid stirring. A rapid delivery pipette was calibrated under the experimental conditions and used to withdraw aliquots at definite times. These results were compared with those obtained in separate experiments in which the complete reaction volume was used. Table I gives some typical results showing that the withdrawal method gives accurate values. It was therefore adopted. A study was also made of the errors involved in the iodometric method of analysis, *e.g.* those due to volatilization of iodine, reaction of iodine with unchanged formate ions, and photochemical oxidation of hydriodic acid. Such errors are negligible if a large excess of potassium iodide and low acidities are used and if the titration with thiosulphate is performed rapidly in diffused light.

During the oxidation, which takes place according to the equation

$$2MnO'_4 + 3HCOO' + H_2O \rightarrow 2MnO_2 + 3CO_2 + 5OH',$$

the pH of the solution increases, and this has been followed by using a glass electrode system. During a typical run the pH increased from 8·90 to 9·72. In the oxidation of formic acid, it was found (4) that hydrogen ions exerted a secondary effect by suppressing the ionisation of the formic

TABLE I.

10 ML. $KMnO_4$ (0·04056 M.); 15 ML. HCOONa (0·03921M.). TOTAL VOL. OF REACTION MIXTURE 250 ML. TEMP. 25·02° C.

Time in minutes.	Ml. 0·1 N thiosulphate	
	from analysis of total volume.	from analysis of aliquot and calculation to total volume.
1½	1·50	1·52
3	2·52	2·50
5	3·83	3·84
7½	5·20	5·20
10	6·31	6·32
12½	7·55	7·53
15	8·28	8·30

acid, and small abnormalities in the initial stages were thought to be due to some specific effect of these ions. Consequently, runs have been carried out in the presence of borax buffers at a constant pH of 9·18. No differences in rates were obtained as long as the ionic strengths of the buffered and unbuffered solutions were the same. Variation in hydrogen ion concentration during the oxidation has therefore no effect on the reaction mechanism.

The formic acid/permanganate reaction is of the second order kinetically and the reaction mixtures were made up to contain initially sodium formate and potassium permanganate in a molar ratio of 3 : 2. This allows the use of the expression

$$k = (1/t.a.)(T_0 - T_t)/(T_t - T_a),$$

where T_0 is the initial oxidising power of the permanganate in ml. N/10 thiosulphate,

T_t, the oxidising power at time t minutes,

T_a, the oxidising power at the end of the reaction and can be shown to be 2/5 T_0,

a, the initial concentration of the reactants in g. mol./l,

and k is the bimolecular constant in g. mol/l./min.

The values of k obtained by this equation are very sensitive to variations, and deviations from second order rate are easy to detect. Table II gives results of a typical run, the constancy of the k values showing clearly how closely the above expression is obeyed.

TABLE II.

10 ML. $KMnO_4$ (0·04127 M.); 16·5 ML. HCOONa (0·03744 M.). TOTAL VOL. OF REACTION MIXTURE 250 ML. TEMP. 24·86° C.

Time in minutes.	Ml. 0·01197 N thiosulphate.	k in g.mol./l./min.
0	9·72	..
4	8·00	39·4
8	7·09	39·5
12	6·52	39·2
16	6·10	39·5
20	5·81	39·6
24	5·53	39·6
30	5·31	39·7

The rate-determining reaction of the formate ion oxidation, suggested by Mann and Tompkins, was

$$MnO'_4 + HCOO' \rightarrow MnO'_3 + CO_2 + OH'.$$

According to the Brönsted theory of the primary salt effect, the addition of neutral salts should cause an acceleration characterised by the equation $ln(k_{obs.}/k_0) = 2aZ_aZ_b\sqrt{\mu}$, where $k_{obs.}$ is the bimolecular constant at the ionic strength μ, k_0 is this constant extrapolated to zero ionic strength, Z_a and Z_b are the electrical charges on the reactant ions, and a is a constant, which for water at 25° C. equals 0·505, if the logarithms are converted to the base 10. Substituting for $Z_a = Z_b = -1$, this becomes

$$\log_{10}(k_{obs.}/k_0) = \sqrt{\mu},$$

or the slope of the plot of this should be unity.

Variations in the ionic strength have been obtained by the addition of M/30 potassium sulphate, and Table III summarises the results obtained.

TABLE III.

μ.	$\sqrt{\mu}$.	k in g.mol./l./min.
0·004122	0·06421	35·48
0·008122	0·09012	37·40
0·01212	0·1101	39·00
0·02412	0·1553	42·30
0·04412	0·2100	47·18
0·08413	0·2901	49·50

Fig. 1 shows the plot of these values, which is a straight line at the lower ionic strengths with a limiting slope of 0·90. The divergence from unity is probably due to the use of ionic strengths higher than the limiting concentrations for the validity of the Debye-Hückel theory, and to the effect of the divalent sulphate ion, since it is known that divergences may be anticipated with multivalent ions. It was, however, impossible to employ in the place of potassium sulphate either the chloride (which reacts

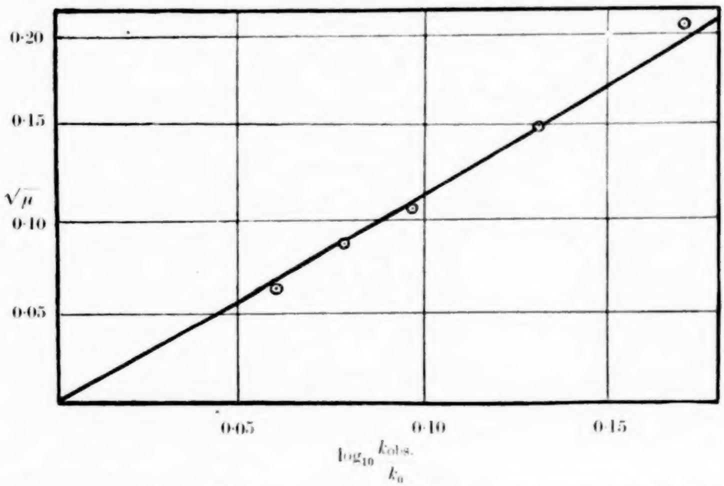

FIG. 1 represents the plot of the square root of the ionic strength against $\log_{10} k_{obs.}/k_0$. ($k_{obs.}$ and k_0 are defined in the text.)

with permanganate) or the nitrate (which reacts with the formate). Nevertheless the value obtained gives a clear indication that the rate-determining process is one involving the collision of two similarly charged univalent ions. The experimental value of the velocity constant of 39·0 at the ionic strength of 0·1212 at 24·86° C. above agrees well with that obtained in Part III of this series, where a figure of 38·0 at the slightly lower ionic strength of 0·1081 at 23·10° C. was obtained.

The activation energy of the reaction, using formic acid, has been found by Mann and Tompkins (4) to be 12,100 cals. Holluta (*loc. cit.*) gives as the temperature coefficient of the velocity constant in the temperature range 17°–26·75° a value of 0·188, from which the activation energy can be calculated as 10,800 cals. Further investigation was therefore necessary to clear up this discrepancy. Values of the velocity constant at constant ionic strength have been obtained at different temperatures, using sodium

formate, and these are given in Table IV. Fig. 2 gives the plot of log k_0 against 1/T and shows that the Arrhenius equation is obeyed.

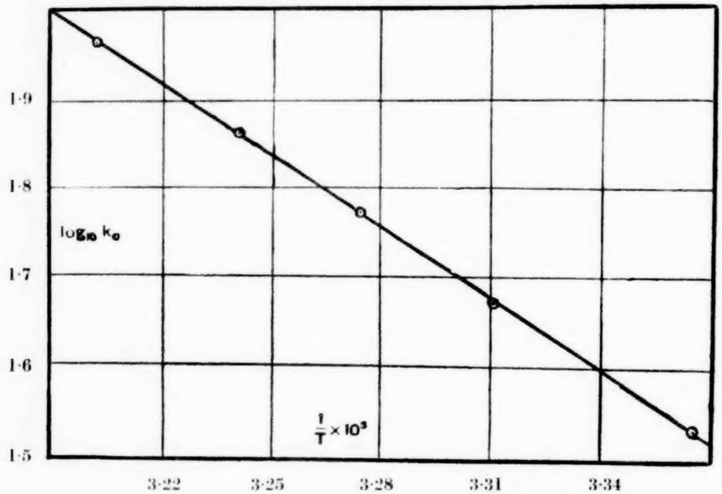

Fig. 2 represents the plot of logarithm of the bimolecular velocity constant (extrapolated to zero ionic strengths) against the reciprocal of the temperature in degrees absolute.

Table IV.

Temperature °C.	Velocity constant k_0 in g.mol./l./min.
24·86	35·48
28·40	44·18
31·42	54·01
34·80	67·80
40·10	92·54

The values given for the velocity constant are extrapolated values for zero ionic strength at each temperature. The activation energy calculated from the slope of the line (fig. 2) is 11,800 cals., which is in good agreement with the figure of 12,100 cals. obtained by Mann and Tompkins in the oxidation of formic acid in the temperature range 15·80°–37·68° at an ionic strength of 0·0875, but is largely different from that of Holluta. His value of 10,800 cals. must now be considered to be inaccurate.

In the oxidation of sodium formate, Holluta proposes

$$MnO_4' + HCOO' + H_2O \rightarrow MnO_4''' + CO_3'' + 3H^{\cdot}$$

as the rate-determining process. Water molecules will thus enter into ternary collisions with the two reactant ions, thereby accounting for the presence of water in the overall reaction. This assumption is shown to be unlikely by a consideration of the molecular statistics of the reaction. The bimolecular constant in g. mol./l./sec. is given by

$$k_0 = (N_0/1000)_1\sigma_2{}^2(8\pi RT(1/M_1 + 1/M_2))^{\frac{1}{2}}.e^{-E/RT}),$$

where N_0 is Avogadro's number, R the gas constant, ${}_1\sigma_2$ the average effective diameter of the reactant ions (taken as 5 A.), T the temperature in degrees absolute, and E the activation energy. This gives a calculated velocity constant which is 35 times larger than the experimental value, but a similar calculation, assuming a process involving ternary collisions, gives a rate which is nearly one thousand times smaller than that obtained experimentally. Since these calculated values involve the square of the average diameter of the ions, which is only approximately known and takes no account of the possibility of a requirement for specific orientation in collision (an essential feature of the hydrogen-atom bridge theory proposed in Part III) the divergence is not surprising. It is therefore more probable that this oxidation proceeds by bimolecular collisions and that the rate-determining reaction does not involve water molecules.

The mechanism previously suggested, *i.e.*

$$MnO_4' + HCOO' \rightarrow MnO_3' + CO_2 + OH' \quad k_1 \quad . \quad (a),$$

$$2MnO_3' + H_2O \rightarrow MnO_2 + HMnO_4' + OH' \quad k_2 \quad . \quad (b),$$

$$HMnO_4' + HCOO' \rightarrow MnO_2 + CO_2 + 2OH' \quad k_3 \quad . \quad (c),$$

where k_1 is assumed to be smaller than k_2 and k_3, accounts for all the features of the formate oxidation, since the rate-determining reaction (*a*) gives the velocity of the overall reaction

$$2MnO_4' + 3HCOO' + H_2O \rightarrow 3CO_2 + 5OH' + 2MnO_2$$

as $k_1(MnO_4')(HCOO')$.

Holluta, however, considers that the slowest step in the formic acid oxidation is given by

$$MnO_4' + HCOO' \rightarrow MnO_4''' + H^{\cdot} + CO_2,$$

and that this is followed by a series of instantaneous or very fast reactions which involve the intermediate $Mn^{\cdot\cdot\cdot}$ and $Mn^{\cdot\cdot\cdot\cdot}$ ions and assumes the possibility of the formation of a complex ion, $Mn(HCOO)_5''$. It has been previously shown (4) that such intermediate ions are ineffective and that such a complex is highly unlikely. In the sodium formate oxidation, the same author proposes a different mechanism and suggests that the reaction

$$MnO_4' + HCOO' + H_2O \rightarrow MnO_4''' + CO_3 + 3H^{\cdot} \quad (d)$$

determines the overall velocity and that this is followed by the instantaneous reaction,

$$2MnO_4''' + HCOO' + 6H^{\cdot} + H_2O \rightarrow 2Mn(OH)_4 + HCO_3' \quad . \quad (e).$$

It is now generally recognised that reactions of such a high order as (*e*) are of no kinetic importance. Moreover, it has been shown above statistically that this latter reaction (*d*) is too slow to account for the observed rate. It may be emphasised that Holluta points out that $Mn^{\cdot\cdot\cdot}$ ions cannot play a predominating rôle in the sodium formate oxidation (although they apparently do in the formic acid reaction (5)). This is in agreement with the mechanism now proposed, and is further supported by the experimental observation that the rate is the same in buffered and unbuffered solutions. The equilibrium $Mn^{\cdot\cdot} + Mn^{\cdot\cdot\cdot\cdot} \rightleftharpoons 2Mn^{\cdot\cdot\cdot}$ is displaced by variation in hydrogen ion concentration.

The conclusion that the mechanism of the oxidation of formic acid and of sodium formate in aqueous solution by potassium permanganate is the same is well-founded since (1) both reactions involve the oxidation of the formate ion, (2) both reactions are kinetically of the second order, (3) the velocity constants have the same magnitude, (4) the agreement in the heats of activation, (5) the rate is adequately explained by the hypothesis of bimolecular collisions between the formate and the permanganate ion.

Summary.

The errors associated with the iodometric method developed in Part I have been studied and have been made negligible. Variation of the hydrogen ion concentration has been found not to affect the characteristics of the reaction, which has been shown to be of the second order. Heats of activation are in agreement with those obtained previously for the formic acid oxidation in Part III, but are different from those which may be calculated from the data of Holluta, which must be regarded as inaccurate. The effect of neutral salts has been investigated and is consistent with the theory that the rate-determining process in this oxidation, as in the oxidation of formic acid, is a bimolecular collision of the formate and the permanganate ions. Further confirmation of this has been obtained by a study of the molecular statistics.

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THE DIURNAL VARIATION OF THE EARTH'S MAGNETIC FIELD AT THE MAGNETIC OBSERVATORY, CAPE TOWN, DURING THE YEARS 1933–1940.

By B. Gotsman.

(Communicated by A. Ogg.)

(With ten Text-figures.)

(Read November 19, 1941.)

As the Magnetic Observatory at Cape Town (Latitude 33° 57′ S., Longitude 18° 28′ E.) has now ceased operation and has been transferred to Hermanus, to avoid interference by the Cape Town suburban electric railways, it has been deemed advisable to analyse the results for the years 1933–1940, the period during which the Cape Town Observatory was in operation, to obtain the mean diurnal variations during these years.

On account of the regular season change in the quiet-day variation magnetic field, it is convenient to consider the average value of this field during each month. This is defined by the mean daily inequalities derived from *five* quiet days (*i.e.* those free from magnetic storms and disturbances) per month or from several sets of such days from the same calendar month in different years. The choice of these days for each month was made (prior to the war) by the International Bureau at De Bilt, Holland, from data supplied by a large number of collaborating observatories, distributed over the surface of the earth. However, for the purpose of this analysis, ten quiet days (which include the five international quiet days) have been chosen from each month, as giving a more representative distribution for the month. These are called the "Ten Selected Quiet Days."

Since the diurnal changes from month to month are gradual, it is considered sufficient to group the months into seasons and to determine the variations for seasons instead of for months.

Lloyd's method of grouping has been adopted:

Group I. November, December, January, February, called the Southern Solstice (Summer).

Group II. March, April, September, October, called the Equinoxes.

Group III. May, June, July, August, the Northern Solstice (Winter).

The mean solar diurnal variations of Declination (D), Horizontal Intensity (H), and Vertical Intensity (Z) for each group for the years 1933–1940 have been determined directly from the magnetograms. The North Intensity (X), East Intensity (Y), and Inclination (I) have been derived from these.

The method of derivation of the diurnal variation (D.V.) of X, Y, and I from the recorded values of D, H, and Z is as follows:—

$$X = H \cos D, \qquad Y = H \sin D,$$

hence

$$\Delta X = \Delta H \,.\, \cos D - H \,.\, \sin D \,.\, \Delta D \,.\, \sin 1' \qquad (1)$$

$$\Delta Y = \Delta H \,.\, \sin D + H \,.\, \cos D \,.\, \Delta D \,.\, \sin 1' \qquad (2)$$

The variations of X and Y are obtained from equations (1) and (2), if due regard is paid to the signs of D and X; East Declination and East Intensity are taken as positive.

Again $H^2 + Z^2 = F^2$, where F = Total intensity,

and $Z = H \,.\, \tan I$, where I = Inclination,

hence

$$\Delta I' = (H \,.\, \Delta Z - Z \,.\, \Delta H) / F^2 \,.\, \sin 1' \qquad (3)$$

Equation (3) gives the variation of Inclination. Z downwards is taken as positive, and I is of the same sign as Z.

Diurnal Variation Tables.

These tables are compiled from diurnal variations corrected for non-cyclic change.

When mean hourly values of a magnetic element are derived from a very large number of days, we obtain a smoothly progressing variation representing the regular diurnal change on the average day. If the days are of a particular class, such as the "Ten Selected Quiet Days," the hourly values thus obtained contain a sensible non-cyclic or aperiodic element, which has to be eliminated before we obtain figures which are periodic in the twenty-four hours.

In these tables, the mean value given for any particular hour is actually the mean value for the preceding hour period; *e.g.* the value at 21^h G.M.T. denotes the mean value for the period 20^h–21^h G.M.T.

TABLE I.

Hour, G.M.T.	ΔD, minutes. Group I.	ΔD II.	ΔD III.	ΔH, γ. Group I.	ΔH II.	ΔH III.	ΔZ, γ. Group I.	ΔZ II.	ΔZ III.
1	0·4	0·5	0·5	1·6	2·4	− 0·3	− 1·1	− 0·3	2·9
2	0·2	0·6	0·7	2·0	3·2	1·0	− 1·2	0·1	3·0
3	− 0·2	0·5	0·8	2·9	3·5	1·8	− 2·3	− 0·8	1·9
4	− 0·8	0·5	1·0	4·7	4·2	2·9	− 0·3	2·3	5·1
5	− 1·8	0·4	1·2	8·9	5·5	4·0	− 3·3	1·5	5·6
6	− 3·5	− 0·4	1·7	13·5	8·5	6·1	− 7·0	− 2·0	6·4
7	− 5·4	− 2·5	1·8	**15·5**	13·1	11·5	− **10·5**	− **9·4**	1·8
8	− **6·6**	− 5·4	− 0·5	13·3	**15·1**	15·7	− 3·2	− 7·5	− 1·5
9	− 6·3	− **7·0**	− 2·8	7·8	12·3	**15·8**	5·2	− 3·7	− **6·9**
10	− 4·4	− 6·6	− **4·9**	0·0	5·9	10·5	14·7	6·3	− 5·1
11	− 1·5	− 3·9	− 4·2	− 5·7	− 2·7	1·9	19·5	16·6	− 0·2
12	1·5	− 0·2	− 2·1	− 9·9	− 9·6	− 6·6	**21·1**	23·1	5·3
13	3·9	2·9	− 0·1	− **12·4**	− **12·4**	− 13·6	20·4	**23·3**	**9·8**
14	**5·0**	**4·3**	1·6	− 11·5	− 11·4	− **15·6**	13·3	15·4	8·5
15	4·6	4·1	**2·4**	− 8·2	− 8·8	− 11·8	1·9	2·8	1·9
16	3·5	3·1	1·5	− 4·7	− 5·5	− 5·0	− 8·5	− 8·6	− 7·3
17	2·2	1·8	0·4	− 3·3	− 4·2	− 1·5	− 10·6	− 10·3	− 6·7
18	1·7	1·5	0·2	− 3·9	− 5·1	− 1·9	− **11·6**	− **11·2**	− **8·0**
19	1·7	1·4	0·1	− 4·4	− 5·2	− 2·6	− 8·1	− 8·3	− 5·3
20	1·7	1·3	0·2	− 3·9	− 4·6	− 3·1	− 7·2	− 7·5	− 4·4
21	1·5	1·1	0·2	− 2·7	− 3·4	− 3·3	− 7·0	− 7·1	− 3·9
22	1·1	0·8	0·3	− 1·3	− 2·0	− 2·9	− 6·7	− 6·6	− 2·8
23	0·9	0·7	0·3	0·2	− 0·2	− 2·3	− 4·3	− 4·8	− 0·6
24	0·6	0·5	0·4	1·2	1·6	− 1·1	− 3·2	− 3·3	0·4
Range	11·6	11·3	7·3	27·9	27·5	31·4	32·7	34·5	17·8

$1\ \gamma = 10^{-5}$ Gauss.

[TABLE II.

TABLE II.

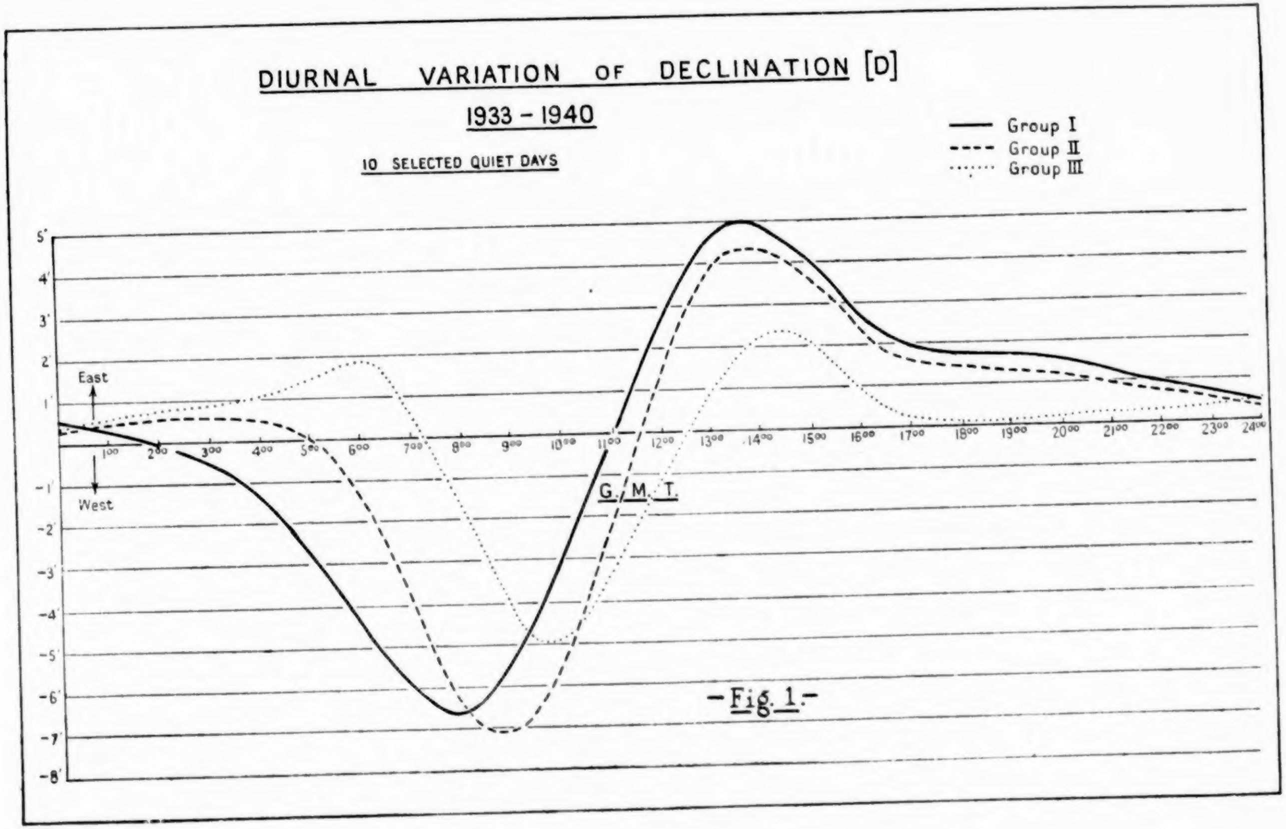
Hour, G.M.T.	$\Delta X, \gamma$.			$\Delta Y, \gamma$.			ΔI, minutes.		
	Group			Group			Group		
	I.	II.	III.	I.	II.	III.	I.	II.	III.
1	2·2	3·1	0·8	0·9	1·0	2·0	0·1	0·2	0·1
2	2·2	3·8	2·1	− 0·2	0·9	2·3	0·2	0·3	0·2
3	2·3	4·1	2·9	− 2·0	0·7	2·4	0·2	0·3	0·3
4	2·9	4·6	4·2	− 5·2	0·3	2·6	0·4	0·5	0·5
5	5·2	5·6	5·5	− 10·9	− 0·7	3·0	0·7	0·6	0·7
6	**6·0**	7·0	8·6	− 19·3	− 4·9	4·2	0·9	0·7	0·9
7	4·6	**7·4**	**13·5**	− 27·3	− 15·2	2·1	1·0	0·8	1·1
8	0·5	4·2	13·2	**− 30·9**	− 27·2	− 8·6	**1·1**	**1·1**	**1·4**
9	− 4·1	− 1·5	8·5	− 27·7	**− 32·8**	− 19·2	1·0	1·0	1·2
10	− 7·6	− 6·3	1·0	− 17·1	− 28·2	**− 23·0**	0·7	0·9	0·8
11	**− 7·7**	**− 9·1**	− 5·5	− 3·4	− 13·9	− 17·0	0·4	0·5	0·2
12	− 6·1	− 8·9	− 9·4	9·9	3·2	− 5·4	0·1	0·2	− 0·4
13	− 4·4	− 6·1	**− 12·4**	20·1	16·3	5·4	− 0·2	− 0·1	− 0·9
14	− 1·5	− 2·8	− 11·2	**23·9**	**21·5**	12·6	− 0·5	− 0·3	**− 1·0**
15	0·8	− 0·7	− 6·5	21·4	19·5	**14·0**	− 0·7	− 0·7	− 1·0
16	1·9	0·6	− 1·9	15·5	14·4	7·8	− 0·8	− 0·9	− 0·8
17	0·9	− 0·4	− 0·6	9·9	8·6	2·0	− 0·8	− 0·9	− 0·5
18	− 0·5	− 1·8	− 1·3	8·3	7·8	1·4	**− 0·9**	**− 1·0**	− 0·6
19	− 1·0	− 2·3	− 2·0	8·4	7·4	1·4	− 0·8	− 0·9	− 0·5
20	− 0·6	− 1·9	− 2·4	8·2	6·8	1·8	− 0·7	− 0·8	− 0·5
21	0·0	− 1·1	− 2·6	6·8	5·8	2·2	− 0·6	− 0·7	− 0·5
22	0·6	− 0·4	− 2·2	4·8	4·3	2·2	− 0·4	− 0·5	− 0·4
23	1·5	0·7	− 1·5	3·3	2·8	2·1	− 0·2	− 0·3	− 0·2
24	2·1	2·0	− 0·7	2·3	1·6	2·0	− 0·1	0·0	− 0·1
Range	13·7	16·5	, 25·9	54·8	54·3	37·0	2·0	2·1	2·4

$1 \gamma = 10^{-5}$ Gauss.

DIURNAL VARIATION CURVES.

Declination (D). Fig. 1.

The general trend of each curve is the same. Commencing at Greenwich midnight to the following midnight, the north end of a compass needle swings from its mean position to the West during the morning. The time of reaching its maximum westerly declination depends on the season. The needle then swings sharply towards the East of the mean position,



DIURNAL VARIATION OF DECLINATION [D]
1933 - 1940
10 SELECTED QUIET DAYS
Group I
Group II
Group III
East
West
G. M. T.
5'
4'
3'
2'
1'
-1'
-2'
-3'
-4'
-5'
-6'
-7'
-8'
1⁰⁰ 2⁰⁰ 3⁰⁰ 4⁰⁰ 5⁰⁰ 6⁰⁰ 7⁰⁰ 8⁰⁰ 9⁰⁰ 10⁰⁰ 11⁰⁰ 12⁰⁰ 13⁰⁰ 14⁰⁰ 15⁰⁰ 16⁰⁰ 17⁰⁰ 18⁰⁰ 19⁰⁰ 20⁰⁰ 21⁰⁰ 22⁰⁰ 23⁰⁰ 24⁰⁰

-Fig. 1.-

and after reaching a maximum in that direction gradually returns to its initial position at midnight. It will be noted that the maximum rate of change occurs when the sun is about its zenith position.

The range of Diurnal Variation, which is the change from maximum West to maximum East, is much the same for Groups I and II; but that for Group III (winter season) is much smaller.

Horizontal Intensity (*H*). Fig. 2.

In all cases, from one Greenwich midnight to the next, the Horizontal Intensity increases during the morning; then sharply decreases towards the afternoon, gradually returning to its initial value.

Here, as in the case of Declination, the maximum rate of change in intensity occurs during daylight hours. The range during the winter season is largest.

Vertical Intensity (*Z*). Fig. 3.

The curves of Declination and Horizontal Intensity show one distinct maximum and minimum, while the Vertical Intensity shows a double oscillation. Generally, the Vertical Intensity decreases during the early morning, rises sharply to a maximum during midday, then decreases sharply again towards afternoon, reaching its second minimum value in the evening and gradually recovers its initial value at the following midnight. Here, the range for Group III is less than that for the other two groups.

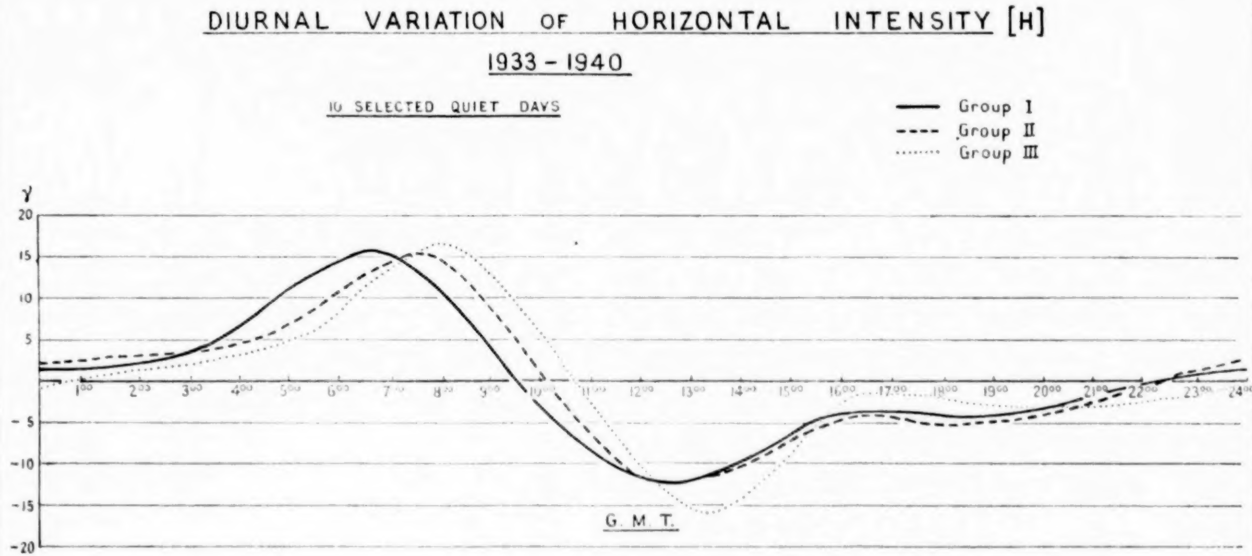
According to convention, the Vertical Intensity is negative in the southern hemisphere; its direction being vertical from the surface of the earth to the zenith.

North and East Intensities (*X and Y*). Figs. 4 and 5.

It will be seen that the X and H curves are similar; also the D and Y curves are very alike. The winter range of the North Intensity is greater than those of Groups I and II, as in the Horizontal Intensity; while the East Intensity ranges of Groups I and II are greater than that of Group III, as in Declination.

Inclination.

A perfectly balanced magnetic needle, free to swing in the magnetic meridian plane around a horizontal axis, which is perpendicular to this plane, is called a "dip needle"; and the angle, which the magnetic axis of this magnet makes with the horizontal, is called the "dip angle" or "inclination." Over most of the southern hemisphere the south pole of the magnetic needle dips below the horizontal and the dip angle is, by convention, negative.

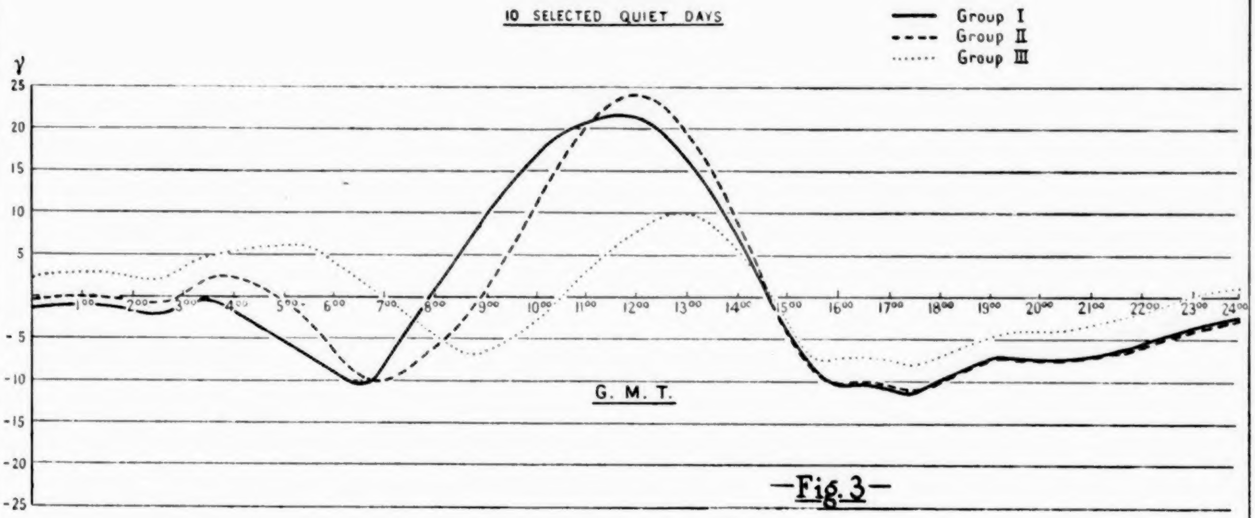

DIURNAL VARIATION OF HORIZONTAL INTENSITY [H]
1933 - 1940
10 SELECTED QUIET DAYS
Group I
Group II
Group III
γ
20
15
10
5
- 5
-10
-15
-20
1⁰⁰ 2⁰⁰ 3⁰⁰ 4⁰⁰ 5⁰⁰ 6⁰⁰ 7⁰⁰ 8⁰⁰ 9⁰⁰ 10⁰⁰ 11⁰⁰ 12⁰⁰ 13⁰⁰ 14⁰⁰ 15⁰⁰ 16⁰⁰ 17⁰⁰ 18⁰⁰ 19⁰⁰ 20⁰⁰ 21⁰⁰ 22⁰⁰ 23⁰⁰ 24⁰⁰
G. M. T.

—Fig. 2—

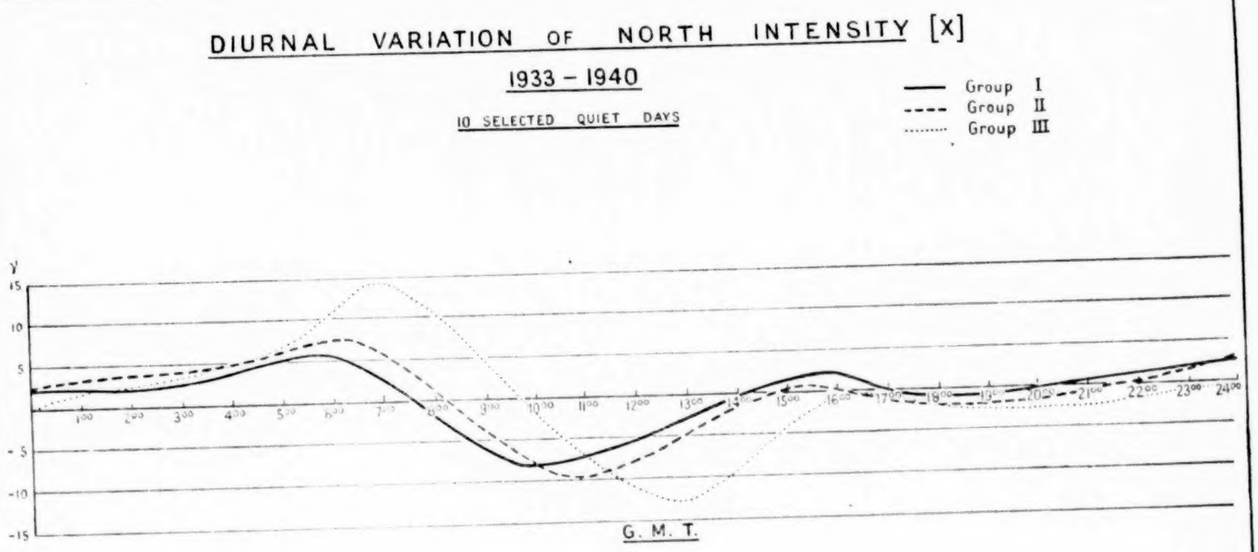
DIURNAL VARIATION OF VERTICAL INTENSITY [Z]

1933 – 1940

10 SELECTED QUIET DAYS



—Fig. 3—

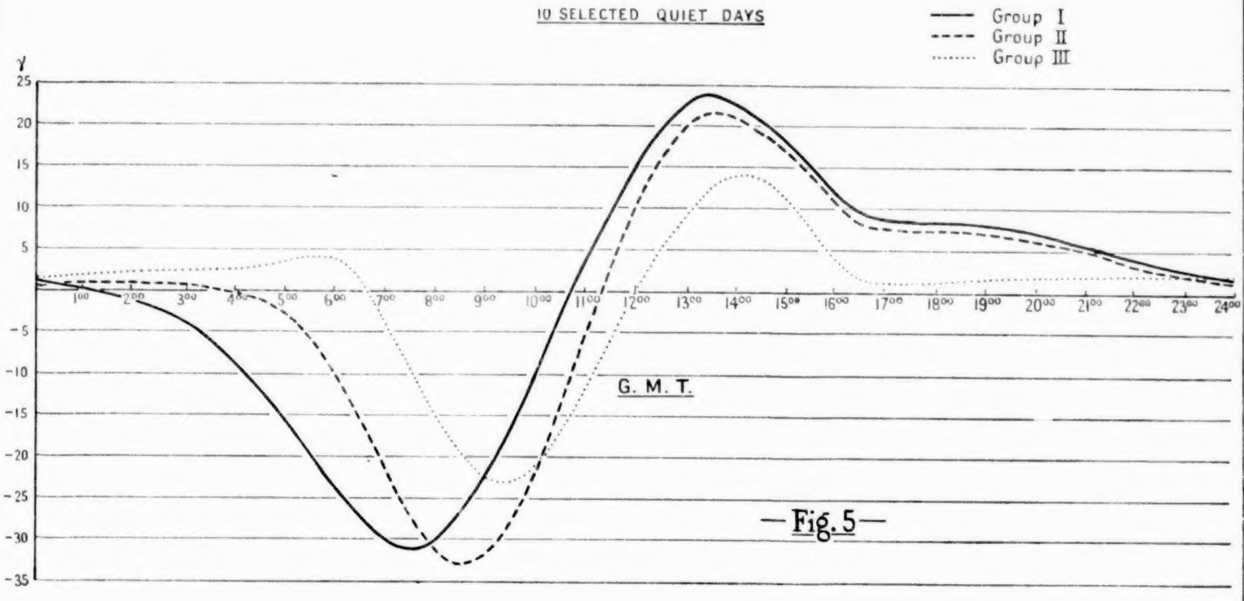

DIURNAL VARIATION OF NORTH INTENSITY [X]
1933 - 1940
10 SELECTED QUIET DAYS
Group I
Group II
Group III
γ
15
10
5
-5
-10
-15
1^00 2^00 3^00 4^00 5^00 6^00 7^00 8^00 9^00 10^00 11^00 12^00 13^00 14^00 15^00 16^00 17^00 18^00 19^00 20^00 21^00 22^00 23^00 24^00
G. M. T.

—Fig. 4—

DIURNAL VARIATION OF EAST INTENSITY [Y]

1933 – 1940

10 SELECTED QUIET DAYS



—Fig. 5—

Fig. 6 shows that from midnight G.M.T. the inclination gradually becomes numerically smaller, the south pole of the needle moving towards the zenith. During daylight hours it passes from a numerical minimum to a numerical maximum in the evening; that is, the south pole moves towards the nadir, and then gradually returns to its initial value at the following midnight.

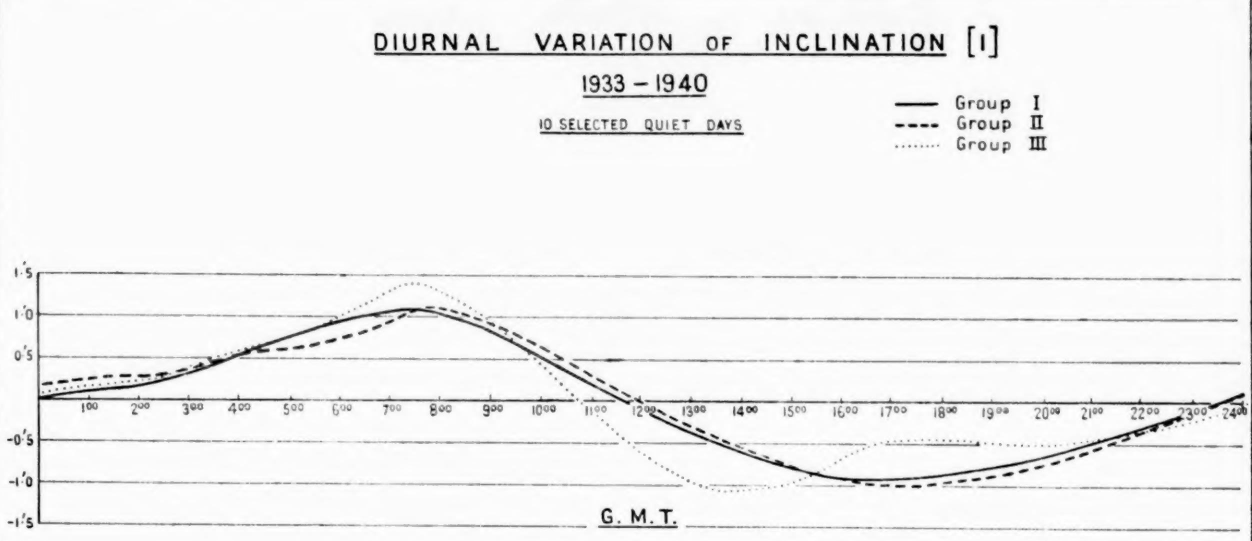
Vector Diagrams.

The curves represented by figs. 1 to 6, giving the quiet-day variation field, indicate that the daily *changes* are much greater during the hours of sunlight than during those of darkness. These curves, however, only show the diurnal change in single elements. The most complete representation of the quiet-day variation field of magnetic force would be that afforded by a model, obtained by drawing from a fixed origin, for each hour of the twenty-four, a series of lines or vectors, representing in direction and intensity the resultant force to which the diurnal variation or inequality may be ascribed.

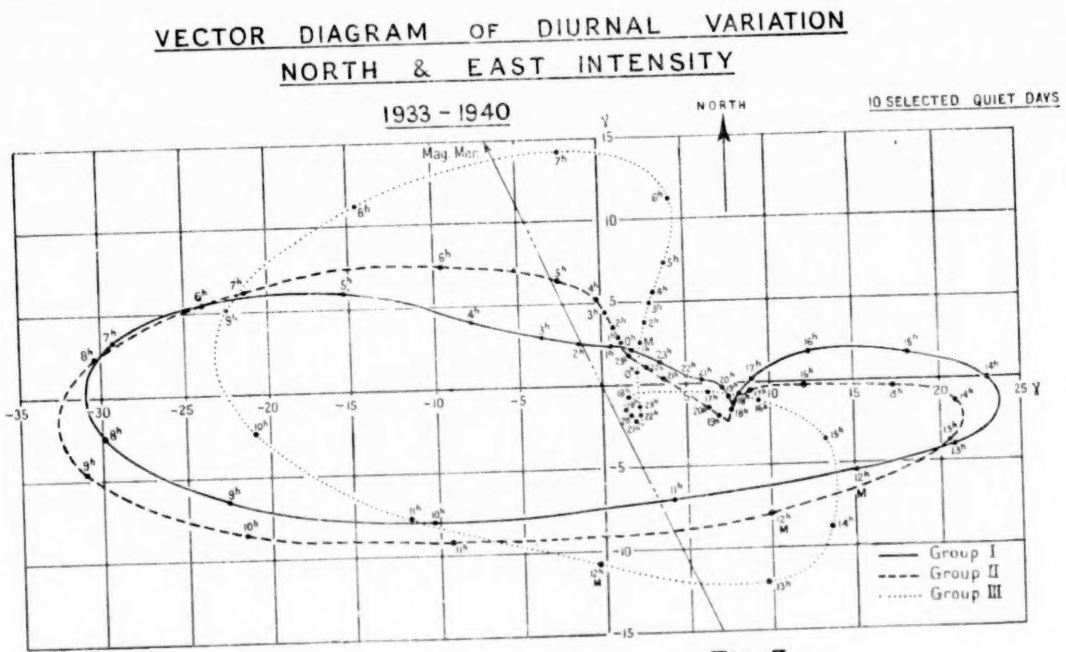
If ΔX, ΔY, ΔZ represent the difference between the force X, Y, Z at each common hour and its mean value for the day, then the vector in question will have ΔX, ΔY, ΔZ for its three rectangular components. On paper it is not possible to represent such a model except by means of stereograms. We can, however, obtain an idea of its character from the projections of the vector in question on three co-ordinate planes. The projection on the horizontal plane which has ΔX, ΔY for its co-ordinates, however, is sufficient to give its character, for it combines the information afforded by the daily inequalities in H and D. The term vector diagram has usually been given to the curve in the horizontal plane.

Fig. 7 gives vector diagrams for the three groups. The curves are described continuously in a counter-clockwise direction; those for Groups I and II are more elongated in the E.-W. direction than that of Group III. In all three diagrams the angular velocity around midnight G.M.T. is relatively small in all three groups, particularly in Group III. From about 6^h to 15^h the area swept out by the vector is very much greater than that described during the night hours. It will be further noted that the diagrams for Groups I and II both show a small bay or re-entrant portion between the hours 18 to 21, whereas the curve for Group III has a loop during the same period. The vector diagrams have their maximum westerly elongations at about 8^h and maximum easterly elongation at about 14^h for both the summer and equinoctial groups, whilst the corresponding elongations occur at 7^h and 14^h for the winter groups.

Table III gives further details regarding the motion of the vector, on its counter-clockwise motion throughout the twenty-four hours.


DIURNAL VARIATION OF INCLINATION [I]
1933 – 1940
10 SELECTED QUIET DAYS
Group I
Group II
Group III
1'5
1'0
0'5
-0'5
-1'0
-1'5
1⁰⁰
2⁰⁰
3⁰⁰
4⁰⁰
5⁰⁰
6⁰⁰
7⁰⁰
8⁰⁰
9⁰⁰
10⁰⁰
11⁰⁰
12⁰⁰
13⁰⁰
14⁰⁰
15⁰⁰
16⁰⁰
17⁰⁰
18⁰⁰
19⁰⁰
20⁰⁰
21⁰⁰
22⁰⁰
23⁰⁰
24⁰⁰
G. M. T.

— Fig. 6.—


VECTOR DIAGRAM OF DIURNAL VARIATION
NORTH & EAST INTENSITY
1933 - 1940
NORTH
10 SELECTED QUIET DAYS
Mag. Mer.
Group I
Group II
Group III

—Fig. 7—

TABLE III.

GROUP.	Vector passing through meridian		Vector passing through mean position of magnetic meridian	
	North.	South.	East to West.	West to East.
	h m	h m	h m	h m
I	1 20	10 45	1 55	10 55
II	3 45	11 25	5 05	11 35
III	6 45	12 03	7 20	12 35

From the above table it will be seen that there is a considerable difference between the times of the vector crossing the magnetic meridian from East to West.

Harmonic Analysis.

In the case of mean diurnal inequalities based on hourly readings from a very large number of days, one may safely assert that the inequality or variation can be represented by a finite number of terms of a Fourier series with such accuracy that the difference between the observed values and those calculated from the harmonic components are less than the instrumental corrections. The number of terms to which the series is carried is usually four: being the first, second, third, and fourth harmonics of periods 24, 12, 8, and 6 hours respectively.

The Fourier coefficients of the quiet-day magnetic field for the elements X, Y, and Z at a number of stations scattered over different parts of the earth's surface afford the most convenient material for the spherical harmonic analysis of this field, which in turn leads to a determination of the intensity and distribution of the system of horizontal electric currents in the upper atmosphere that could produce this quiet-day magnetic field.

The Fourier analysis of a diurnal variation may be expressed in either of the equivalent forms:

$$a_1 \,.\, \cos t + b_1 \,.\, \sin t + a_2 \,.\, \cos 2t + b_2 \,.\, \sin 2t \; + \; . \; . \; .$$

$$c_1 \,.\, \sin (t + \alpha_1) + c_2 \,.\, \sin (2t + \alpha_2) + \; . \; . \; .$$

or simply, $\Sigma c_n \,.\, \sin (nt + \alpha_n)$ where $n = 1,2,3,4,$

and a_1, b_1, c_1, and α_1 are known as Fourier coefficients, while t denotes the time; one hour in t counting 15°. The a, b constants are calculated directly from the twenty-four hourly values in the diurnal variation. c (the amplitude) and α (phase angle) coefficients are then deduced by the usual formulae, viz.

$$\alpha_n = \tan^{-1}(a_n / b_n)$$

and $c_n = \sqrt{(a_n{}^2 + b_n{}^2)}$ where $n = 1, 2, 3, 4.$

An increased value of a phase angle means an earlier occurrence of the maxima and minima of the term involved; one hour of time in α_1 being

15°; 30° in a_2; 45° in a_3; 60° in a_4, and so on. The substitution of L.M.T. (local mean time) for G.M.T. makes no difference to the amplitudes, but alters the phase angles.

If we wish to replace a Fourier series in which t represents G.M.T. by one in which t denotes L.M.T. at a station in longitude $\lambda°$ E. we diminish a_1 by λ, a_2 by 2λ, and so on. As the magnetic observatory at Cape Town is in longitude 18° 28′ E. of Greenwich, a_1 would have to be diminished by 18°·47; a_2 by 36°·94, etc.

In this paper only the curves for the 1st, 2nd, 3rd, and 4th harmonics of the series for the diurnal variation of Declination have been drawn, as the higher harmonics are negligible.

TABLE IV.

Harmonic Components of the Diurnal Variation of Declination and Magnetic Intensities.

Ten Selected Quiet Days from each month of the years 1933–1940. Values of c_n and a_n, corrected for non-cyclic change, in the series

$$\Sigma c_n \, . \sin (nt + a_n),$$

t being reckoned in hours from Greenwich midnight and converted into arc at the rate of 15° per hour.

Tabular values of c in minutes for Declination and γ for Intensities; a in degrees.

ELEMENT.	GROUP.	c_1.	a_1.	c_2.	a_2.	c_3.	a_3.	c_4.	a_4.
		′	°	′	°	′	°	′	°
Declination (D)	I	3·6	182·7	2·5	38·5	1·2	246·5	0·2	65·2
	II	2·8	166·3	2·7	11·7	1·7	220·2	0·6	66·6
	III	1·1	117·8	1·7	338·1	1·4	182·6	0·7	27·4
		γ	°	γ	°	γ	°	γ	°
Horizontal Intensity (H)	I	8·6	27·7	5·5	256·4	3·3	118·9	0·2	88·8
	II	8·6	21·0	4·7	236·8	3·9	89·7	1·1	296·8
	III	7·8	10·9	6·5	228·7	4·7	59·4	1·4	246·0
Vertical Intensity (Z)	I	9·2	293·1	9·7	99·6	4·8	298·8	0·2	81·0
	II	7·9	294·1	9·6	82·1	5·7	276·6	2·1	100·2
	III	3·3	358·0	4·3	47·9	4·2	233·3	2·5	66·2
North Intensity (X)	I	3·3	78·2	3·1	319·2	2·3	165·3	0·5	76·7
	II	4·6	56·7	3·5	310·5	2·6	145·5	0·8	5·7
	III	6·6	26·5	5·6	258·8	3·5	94·6	0·7	316·4
East Intensity (Y)	I	17·1	187·7	11·7	45·5	5·6	257·2	0·6	64·6
	II	13·8	174·4	11·8	18·8	7·9	220·9	2·6	75·8
	III	6·0	148·7	8·0	358·1	6·8	198·0	3·0	37·5

Curves of Harmonic Components of Declination.

GROUP I. Fig. 8.—The amplitudes decrease steadily as the harmonics increase; the fourth harmonic amplitude being about 4 per cent. that of the first.

GROUP II. Fig. 9.—The amplitudes of all the harmonics are more uniform than in Group I. The first and second harmonics have almost the same amplitude, while the amplitudes of the third and fourth harmonics are about 7 per cent. and 20 per cent. respectively that of the first harmonic.

GROUP III. Fig. 10.—The amplitudes of the second and third harmonics are nearly equal, but greater than that of the first. The amplitude of the fourth harmonic is about 60 per cent. that of the first.

In each figure the sum of the four harmonics has been drawn, giving a resultant curve which is practically identical with the curves of fig. 1, which shows that the higher components are negligible.

Group I. The first harmonic component is given by:

$$3{\cdot}6 \sin (t + 182^\circ{\cdot}7),$$

which has a maximum value when the argument is 90°, 450°, etc.

For a maximum $(t + 182^\circ{\cdot}7) = 450^\circ$.

Hence $t = 267^\circ{\cdot}3 \equiv 17^h{\cdot}8 = 17^h\ 48^m$ G.M.T.

A minimum occurs twelve hours earlier, at $5^h\ 48^m$. The range is $7'{\cdot}2$.

The second harmonic component is given by:

$$2{\cdot}5 \sin (2t + 38^\circ{\cdot}5),$$

which has maximum values when

$$(2t + 38^\circ{\cdot}5) = 90^\circ \text{ and } 450^\circ,$$

whence $t = 25^\circ{\cdot}75 \equiv 1^h{\cdot}72 = 1^h\ 43^m$ and $13^h\ 43^m$ G.M.T.

The minimum values are at $7^h\ 43^m$ and $19^h\ 43^m$, and the range is $5'{\cdot}0$.

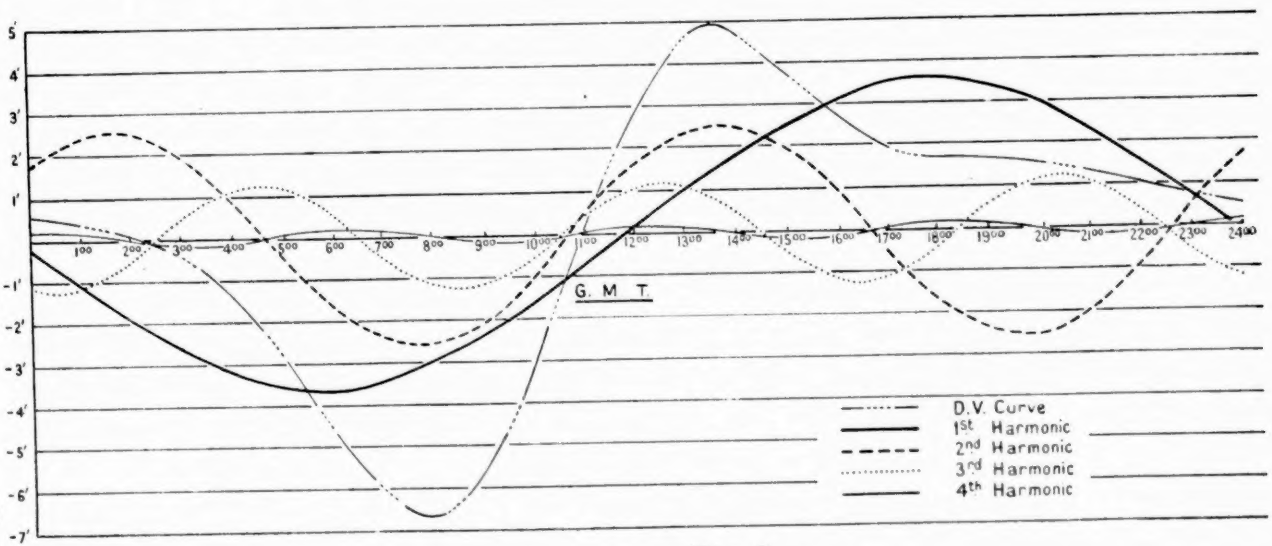
The data required for this paper were obtained from the observatory records. During the years 1938–1940 Mr. A. M. van Wijk was chiefly responsible for the observational work at the observatory. I wish to express my thanks to Dr. A. Ogg for placing the observational data at my disposal for the purpose of this analysis.

MAGNETIC OBSERVATORY,
HERMANUS,
November 1941.

DIURNAL VARIATION OF DECLINATION 1933-1940

HARMONIC ANALYSIS

10 SELECTED QUIET DAYS —— GROUP I

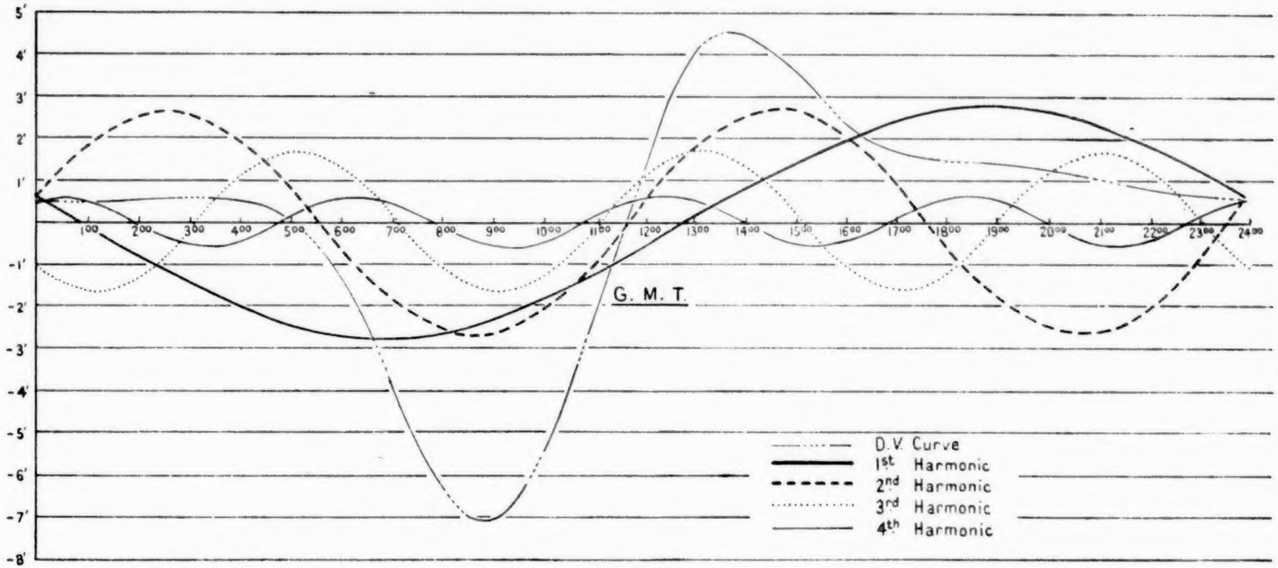


—Fig. 8—

DIURNAL VARIATION OF DECLINATION 1933-1940

HARMONIC ANALYSIS

10 SELECTED QUIET DAYS — GROUP II

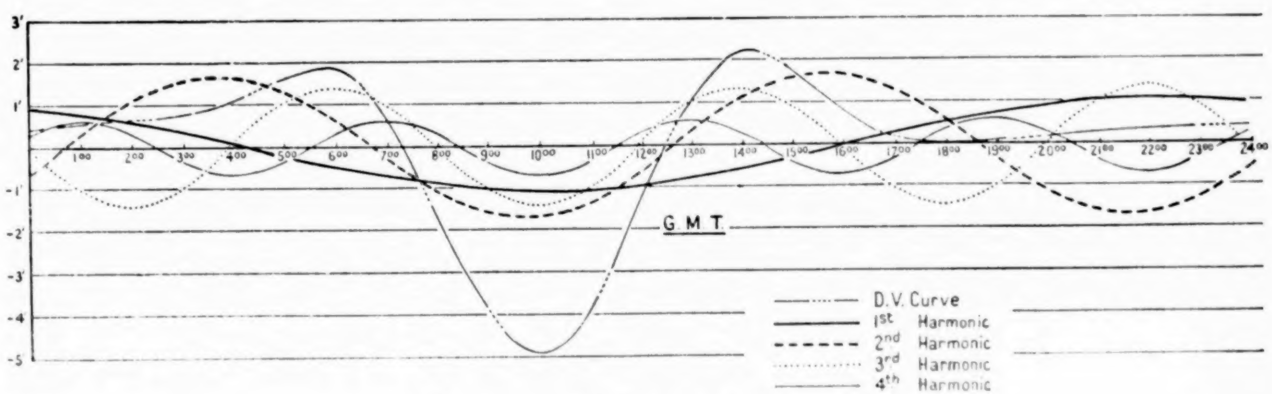


—Fig. 9—

DIURNAL VARIATION OF DECLINATION 1933 - 1940

HARMONIC ANALYSIS

10 SELECTED QUIET DAYS —— GROUP III



—Fig. 10—

NEW SPECIES OF SOUTH AFRICAN RESTIONACEAE.

By N. S. Pillans.

(Communicated by H. M. D. Bolus.)

(Read November 19, 1941.)

Since the publication of my monograph of the African Restionaceae in Volume XVI (1928) of these *Transactions* a considerable quantity of material has been added to the collection of Restionaceae in the Bolus Herbarium, University of Cape Town. The new species described in this paper are founded on some of that material.

RESTIO, *Linn.*

R. Acockii, sp. nov.; culmis simplicibus vel parce ramosis gracilibus compressissimis; vaginis arte convolutis mucronatis coriaceis; spiculis masculis cylindricis in cymas spicatas vel paniculatas dispositis; bracteis ovatis obtusis; perianthio oblongo basin versus attenuato; segmentis lineari-oblongis membranaceis, exterioribus lateralibus villoso-carinatis; spiculis femineis masculinis conformibus plurifloris; bracteis ut in mare; perianthio oblongo; segmentis exterioribus oblongo-lanceolatis acutis, lateralibus villoso-carinatis; segmentis interioribus lanceolatis; ovario rotundato biloculari; stylis tribus liberis.

Stems mostly 60–80 cm. high, simple or sparingly branched, wiry, much compressed, 2–2·5 mm. thick at the middle, minutely wrinkled. Sheaths mostly 2–2·5 cm. long, closely convolute, acute, subulate-mucronate, coriaceous, entirely brown. Male spikelets several or many in a spicate or paniculate cyme, 1·5–2 cm. long, about 2 mm. wide, cylindric, acute at both ends. Spathe closely embracing the base of the spikelet, ovate, short and bract-like. Bracts tightly imbricate, 5–6 mm. long, ovate, obtuse, cartilaginous, pale brown, with a membranous dark brown upper margin. Perianth about 4 mm. long, oblong, tapered from the middle to the base: segments linear-oblong, membranous; the outer lateral acute, villous-carinate; the anterior glabrous; the inner slightly shorter, obtuse. Female inflorescence and spikelets similar to the male, many-flowered. Bracts as in the male. Perianth about 4 mm. long, oblong, stipitate: outer segments

oblong-lanceolate, acute, cartilaginous; the lateral villous-carinate: inner segments slightly shorter, lanceolate, cartilaginous, with membranous margins. Ovary rotundate, 2-chambered. Styles 3, adjacent, free. Capsule 2-seeded.

Cape Province.—STELLENBOSCH DIV.: Brackenfel, sandy flats, *Acock*, 4158, ♂, 4159, ♀ (type, in Bolus Herbarium).

In floral characters this species has an affinity with *R. bifurcus*, Nees, and the unusual coloration of the bracts is common to the two species. The very compressed stems, however, distinguish the new species from any other with similar spikelets or flowers.

R. Burchellii, sp. nov.; culmis parce ramosis vel simplicibus gracilibus teretibus laevibus; vaginis subtruncatis mucronatis, marginibus superioribus caducis; spiculis masculis obovatis in cymas spicatas vel paniculatas dispositis; bracteis rotundatis brevissime mucronatis; perianthio elliptico; segmentis oblongo-lanceolatis acutis, exterioribus lateralibus villoso-carinatis; spiculis femineis in cymas spicatas vel paniculatas dispositis obovatis 3–4-floris; bracteis ellipticis obtusissimis; perianthio elliptico; segmentis lanceolatis, exterioribus lateralibus villoso-carinatis; ovario rotundato biloculari; stylis duobus liberis.

Stems 30–50 cm. high, tufted, sparingly branched or simple, wiry, terete, smooth, minutely white-speckled. Sheaths at the middle of the stems about 1 cm. long, closely convolute, coriaceous, brown, abruptly narrowed into a subulate mucro, with a caducous membranous upper margin. Male spikelets several or many in a spicate or paniculate cyme, obovate, 0·8–1·2 cm. long. Spathe sheath-like, clasping only the base of the spikelet. Bracts about 4 mm. long, closely imbricate, rotundate, widely rounded at the upper end, with a very short blunt mucro, coriaceous, pale brown, with a red-brown membranous upper margin. Perianth often partly protruding, about 4 mm. long, elliptic: outer segments oblong-lanceolate, acute, cartilaginous; the lateral navicular, densely villous on the upper half of the carina: inner segments slightly shorter, oblong-lanceolate, membranous. Female spikelets several or many in a spicate or paniculate cyme, about 1 cm. long, obovate, 3–4-flowered. Spathe as in the male. Bracts closely imbricate, about 6 mm. long, elliptic, widely rounded at the upper end, coriaceous, light brown, with a dark brown membranous upper margin. Perianth often partly protruding, 4–5 mm. long, elliptic: outer segments lanceolate, acute; the lateral navicular, densely villous on the upper half of the carina: inner segments about as long, ovate-lanceolate. Ovary rotundate, 2-chambered. Styles 3, adjacent, free. Capsule 2-seeded.

Cape Province.—CALEDON DIV.: mountains at Houw Hoek, *Burchell*, 8119, ♂; Nieuweberg, *Stokoe*, 3187, ♂ and ♀ (type, in Bolus Herbarium);

Somerset Sneeuwkop, *Stokoe*, 6713, ♂ and ♀, *Esterhuysen* 3578 ♂; Landdrost Kop, *Stokoe*, 4014, ♂, *Esterhuysen* 3579, ♀; between Viljoen's Pass and Somerset Sneeuwkop, *Stokoe*, 7042, ♂ and ♀.

There is a close affinity between this species and *R. praeacutus*, Mast., from which it differs in its smooth stems, bracts widely rounded at the upper end, smaller spikelets of the female plant and outer lateral segments of the perianth more amply villous on the carina.

R. obscurus, sp. nov.; culmis parce ramosis gracilibus teretibus laevibus; vaginis attenuatis mucronatis; spiculis masculis obovatis in cymas spicatas dispositis; bracteis ellipticis obtusis mucronatis, marginibus superioribus laceratis membranaceisque; perianthio elliptico; segmentis exterioribus oblongo-lanceolatis acutis, lateralibus villoso-carinatis; segmentis interioribus oblongo-lanceolatis obtusis; spiculis femineis masculinis conformibus sed angustioribus; bracteis ut in mare; perianthio ovato-lanceolato; segmentis exterioribus lanceolatis, lateralibus villoso-carinatis; segmentis interioribus ovatis obtusis; ovario rotundato biloculari; stylis tribus liberis.

Stems about 80 cm. high, moderately or sparingly branched, rarely simple, wiry, about 1·5 mm. thick at the middle, terete, smooth, grey-speckled. Sheaths at the middle of the stems about 1·5 cm. long (excluding mucro), closely convolute, narrowed into a mucro 3–4 mm. long, coriaceous, broadly membranous at the upper margin. Male spikelets about 8 mm. long, obovate, several or many in solitary or clustered spicate cymes. Spathe reaching to about the middle of the spikelet, rotundate, coriaceous, stoutly mucronate, with a deciduous membranous upper margin. Bracts 4–5 mm. long, closely imbricate, elliptic, obtuse, shortly and stoutly mucronate, cartilaginous, with a deeply lacerate pale-membranous upper margin, otherwise brown. Perianth stipitate, shortly exceeding the bract, about 4 mm. long, elliptic: outer segments oblong-lanceolate, acute, cartilaginous; the lateral navicular, villous-carinate; the anterior glabrous: inner segments much shorter, oblong-lanceolate, obtuse, membranous. Female spikelets about 7 mm. long, resembling the male and similarly arranged but narrower, with 1 perfect flower. Spathe and bracts as in the male. Perianth shortly stipitate, 5–6 mm. long, ovate-lanceolate: outer segments lanceolate, cartilaginous; the lateral navicular, villous-carinate; the anterior villous only at the apex: inner segments slightly shorter, ovate, obtuse, cartilaginous, membranous at the margins. Ovary rotundate, 2-chambered. Styles 3, adjacent at base, free. Capsule 2-seeded.

Cape Province.—Paarl Div.: Seven Sisters Mountain, *Stokoe* in Bolus Herbarium, 22641, ♂ and ♀ (type); Bushman's Castle Mountain, *Stokoe* in Bolus Herbarium, 22642, ♂.

The affinity is with *R. pachystachyus*, Kunth and *R. brunneus*, Pillans,

from which it is chiefly distinguished by its much smaller spikelets, and by the female spikelet having only 1 perfect flower.

R. papyraceus, sp. nov.; culmis simplicibus gracilibus teretibus, basi striatis; vaginis laxe convolutis acutis aristatis; spiculis masculis ellipticis vel rotundatis in cymas spicatas dispositis; bracteis oblongo-lanceolatis acutissimis papyraceis; perianthio stipitato elliptico-oblongo; segmentis exterioribus lineari-lanceolatis, lateralibus villoso-carinatis; segmentis interioribus brevioribus; spiculis femineis bracteisque ut in mare; perianthio oblongo-elliptico; segmentis exterioribus oblongo-lanceolatis cartilagineis, lateralibus villoso-carinatis; segmentis interioribus ovato-lanceolatis obtusis membranaceis; ovario orbiculari biloculato; stylis duobus liberis.

Stems crowded, about 60 cm. high, unbranched, wiry, terete, striate at base, thence wrinkled longitudinally to near the middle, thence smooth. Sheaths 2–3 cm. long, very loosely convolute, acute, shortly awned, coriaceous, pale-membranous at the upper margin. Male spikelets several in a spicate cyme, elliptic or rotundate, about 1·5 cm. long. Spathe sheath-like, reaching to shortly beyond the middle of the spikelet. Bracts very loosely imbricate, 1–1·3 cm. long, oblong-lanceolate, very acute, papery, light brown, paler and membranous at the margins, perianth distinctly stipitate, about 6 mm. long, elliptic-oblong: outer segments linear-lanceolate, acute, cartilaginous; the lateral navicular, villous-carinate; the anterior glabrous: inner segments much shorter, lanceolate, obtuse, membranous. Female spikelets one to several in a spicate cyme, resembling the male, about 2 cm. long, many-flowered. Bracts as in the male. Perianth about 6 mm. long, oblong-elliptic, on a stipe 1–1·5 mm. long: outer segments oblong-lanceolate, acute, cartilaginous; the lateral navicular, villous-carinate; the anterior glabrous: inner segments much shorter, ovate-lanceolate, obtuse, membranous. Ovary orbicular, 2-chambered. Styles 2, widely separated, accompanied by the rudiments of a third.

Cape Province.—Ladismith Div.: west of Klein Zwartberg Peak, damp ledges facing south, alt. 6700 feet, *Stokoe*, 1925, ♂ and ♀ (type, in Bolus Herbarium), *Andreae*, 1276, ♂.

A distinct species without any apparent close affinity. The presence of the vestige of a third style is interesting evidence of the reduction of the number of styles in the genus.

CHONDROPETALUM, *Rottb.*

C. Acockii, sp. nov.; culmis simplicibus gracilibus; vaginis persistentibus subulato-mucronatis; inflorescentia mascula oblonga paniculata; spiculis rotundatis plurifloris; bracteis orbicularibus; perianthio ovato; segmentis obtusis, exterioribus ovatis, interioribus ellipticis conspicue

longioribus; inflorescentia feminea lineari-oblonga paniculata; spiculis orbicularibus 2–4-floris; bracteis rotundatis vel orbicularibus; perianthio trigono; segmentis subaequalibus, exterioribus obovatis, lateralibus paulum carinatis; ovario trigono; stylis tribus.

Stems about 70 cm. high, scattered along creeping rhizomes, wiry, 1–1·5 mm. thick at the middle, unbranched. Sheaths 2–3 cm. long, persistent, closely convolute, coriaceous, light brown, subulate-mucronate, with a deciduous pale-membranous upper margin and a permanently acute apex. Male inflorescence a rather crowded oblong panicle 5–10 cm. long. Spathe sheath-like but smaller, deciduous. Spathellae ovate-lanceolate, membranous. Spikelets about 3 mm. long, rotundate, compact, about 6-flowered, chestnut-brown. Sterile bracts at the base of the spikelet about 2. Fertile bracts about 1·5 mm. long, orbicular, widely rounded at the apex, deeply concave, cartilaginous. Perianth subsessile, 2 mm. long, ovate. Segments obtuse, cartilaginous; the outer ovate; the inner elliptic, twice as long. Female inflorescence 4–8 cm. long, linear-oblong, paniculate; the branches bearing one or several spikelets. Spathe sheath-like but smaller, persistent. Spathellae shorter than or as long as the spikelets, ovate, mucronate, membranous. Spikelets about 4 mm. long, orbicular, 2–4-flowered, chestnut-brown. Sterile bracts at the base of the spikelet 1 or 2. Fertile bracts 2–3 mm. long, rotundate or orbicular, widely rounded at the upper end, deeply concave, cartilaginous. Perianth 2·5–3 mm. long, trigonous, cartilaginous: outer segments obovate, subacute; the lateral slightly keeled; the inner similar, slightly longer or as long as the outer. Ovary trigonous, with 2 fertile chambers. Styles 3, separated.

Cape Province.—STELLENBOSCH DIV.: sandy flats near Kraaifontein, *Acock*, 4157, ♂ and ♀ (in Bolus Herbarium).

The affinity is with *C. rectum*, Pillans, from which it is distinguished by having stouter stems, much larger, persistent leaf-sheaths, the spikelets of the male more crowded and with more flowers, and the segments of the female perianth wider and less acute.

ELEGIA, *Linn.*

E. extensa, sp. nov.; culmis gracilibus simplicibus; vaginis caducis mucronatis; inflorescentia mascula dense paniculato-cymosa; bracteis orbicularibus; perianthio rotundato; segmentis rotundatis valde concavis; inflorescentia feminea anguste oblonga paniculato-cymosa; spathellis papyraceis; bracteis orbicularibus; perianthio rotundato trigono; segmentis elliptico-oblongis obtusis, exterioribus lateralibus carinatis, interioribus subequalibus; ovario obovato trigono; stylis tribus.

Stems about 60 cm. high, spaced on creeping rhizomes, wiry, 2 mm.

thick at the middle, unbranched, wrinkled. Sheaths caducous, about 3 cm. long, acute, mucronate, cartilaginous, buff coloured, speckled red-brown. Male inflorescence paniculate-cymose, with several compound branches at each node, oblong, dense, about 6 cm. long. Spathes persisting during the flowering period, sheath-like but smaller. Spathellae 5–8 mm. long, spathe-like. Flowers crowded in rotundate, spike-like clusters of 6–8, red-brown. Bracts about half as long as the flowers, orbicular, membranous. Perianth scarcely 1·5 mm. long, rotundate, very obtuse in bud, red-brown: segments rotundate, very obtuse, concave; the outer half as long as the inner. Female inflorescence 8–10 cm. long, narrowly oblong, paniculate-cymose. Spathes sheath-like, 1·5–3 cm. long. Branches of the inflorescence usually in pairs, 1–3 cm. long, simple or compound. Spathellae mostly 1–1·3 cm. long, spathe-like, papery. Flowers in dense clusters of 3–6. Bracts much shorter than the flowers, orbicular, membranous. Perianth 2 mm. long, rotundate, trigonous, cartilaginous, red-brown: outer segments elliptic-oblong, obtuse; the lateral navicular, carinate: inner segments as long or slightly longer, oblong-elliptic, obtuse. Ovary obovate, trigonous. Styles 3, adjacent.

Cape Province.—TULBAGH DIV.: Wolseley, *Pillans*, 8654, ♂ and ♀ (in Bolus Herbarium).

The affinity is with *E. juncea*, Linn., from which it differs in having the stems spaced along creeping rhizomes, much smaller male flowers obtuse in bud, and pale spathes in the female.

E. Hutchinsonii, sp. nov.; culmis simplicibus vel ramosis paulum rigidis; vaginis subpersistentibus laxe convolutis obtusis mucronatis; inflorescentia mascula anguste paniculata; bracteis nullibus; perianthio ovato; segmentis exterioribus late ovatis acutis; segmentis interioribus late ellipticis obtusis exterioribus duplo longioribus; inflorescentia feminea anguste spicato-cymosa; bracteis solitariis ovato-lanceolatis acutis; perianthio trigono; segmentis exterioribus ovato-lanceolatis acutis; segmentis interioribus rotundatis vel orbicularibus; ovario trigono conico; stylis tribus connatis.

Stems about 70 cm. high, simply or compoundly branched, 2·5–3 mm. thick at the middle, minutely wrinkled. Sheaths mostly 2·5–3·5 cm. long, persisting throughout the flowering period, loosely convolute, elliptic, obtuse, mucronate, coriaceous, chestnut-brown, paler at the margins. Male inflorescence narrowly paniculate-cymose, 4–9 cm. long. Spathes sheath-like, elliptic-oblong, obtuse, mucronate. Branches of the cyme several or many at each node, mostly compound. Bracts absent. Perianth stipitate, 2·5 mm. long, ovate, trigonous: outer segments broadly ovate, acute, membranous: inner segments twice as long, broadly elliptic, obtuse, cartilaginous, light brown. Female inflorescence 3–6 cm. long, very

narrowly spicate-cymose: branches 1 or 2 at each node, one- or several-flowered. Bracts solitary with each flower, about half as long as the perianth, ovate-lanceolate, acute, membranous. Perianth sessile, 4 mm. long, trigonous: outer segments 3 mm. long, ovate-lanceolate, acute navicular, cartilaginous, with membranous margins: inner segments rotundate or orbicular, very widely rounded or almost truncate at the upper end, coriaceous, pale red-brown. Ovary trigonous, narrowed upwards from a broad base, with a tubercle at the base of each angle. Styles 3, stout, connate up to the base of the stigmatic surface.

Cape Province.—Ceres Div.: without precise locality, *Stokoe*, 1434, ♂ and ♀; gorge west of Ceres, *Hutchinson*, 617, ♂ and ♀ (type, in Bolus Herbarium).

A very distinct species, but with some resemblance to *E. grandis*, Kunth and *E. Muirii*, Pillans in the similar habit of branching and structure of the male inflorescence. The three false sutures in the partly developed fruit are remarkable, suggesting an affinity with the genus *Chondropetalum*.

E. Stokoei, sp. nov.; culmis simplicibus gracilibus; vaginis acutis caducis; inflorescentia mascula paniculato-cymosa; bracteis orbicularibus membranaceis; perianthio rotundato; segmentis exterioribus orbicularibus; segmentis interioribus rotundatis obtusissimis; inflorescentia feminea anguste paniculata; bracteis orbicularibus saepe deficientibus; perianthio sessili membranaceo; segmentis exterioribus oblongo-lanceolatis acutis, lateralibus carinatis, apice divergentibus; segmentis interioribus rotundatis obtusis exterioribus subequalibus; ovario elliptico dorse compresso, summa duro; stylis duobus liberis.

Stems about 40 cm. high, simple, about 1 mm. thick, wrinkled, usually accompanied by more slender, branched, sterile stems. Sheaths mostly 2–2·7 cm. long, caducous, elliptic-oblong, acute, coriaceous, chartaceous at the margins, red-brown, minutely speckled with yellow. Male inflorescence 4–8 cm. long, compactly paniculate-cymose, oblong. Spathes persisting during the flowering period, ovate, acute, expanded, 1·5–2·5 cm. long, cartilaginous, coloured like the spathes. Spathellae conspicuous, mostly 5–8 mm. long, ovate, acute, concave, chartaceous. Branches of the inflorescence up to 2 cm. long, several at each node. Bracts 1–1·5 mm. long, orbicular, membranous, closely convolute. Flowers secund, in clusters of 2–4. Perianth 2 mm. long, rotundate: outer segments orbicular, cartilaginous, light brown: inner segments twice as long, rotundate, very obtuse, cartilaginous. Female inflorescence 3–6 cm. long, oblong, compact, with 1 or 2 branches at each node. Spathes persistent, about 1·5 cm. long, sheath-like but paler. Spathellae very conspicuous, hiding the flowers, 6–8 mm. long, ovate, chartaceous. Flowers in pairs or solitary. Bracts about half as long as the flowers, orbicular, often absent. Perianth 2–2·5

mm. long, membranous: outer segments oblong-lanceolate, acute; the lateral carinate, spreading at the apex; the inner about as long, rotundate, obtuse. Ovary elliptic, dorsally compressed, with a broadly conical hard cap. Styles 2, free.

Cape Province.—TULBAGH DIV.: Tulbagh Waterfall, *Stokoe*, 1431, ♂, 1433, ♀ (in Bolus Herbarium).

The affinity is with *E. juncea*, Linn. and *E. parviflora*, Kunth, from which it is chiefly distinguished in having 2 styles.

LEPTOCARPUS, *R. Br.*

L. intermedius, sp. nov.; culmis ramosis gracilibus, partibus inferioribus paulum tuberculatis; vaginis arte convolutis obtusissimis mucronatis, marginibus superioribus late membranaceis; spiculis femineis terminalibus solitariisque oblanceolatis vel cuneatis 2–3-floris; bracteis oblongis obtusis apiculatis, basi valde decurrentibus; perianthio stipitato oblongo; segmentis exterioribus oblongis acutis navicularibus cartilagineis glabris; segmentis interioribus oblongo-lanceolatis obtusis; ovario obovato compresso uniloculato, marginibus crassis; stylis tribus liberis.

Stems 30–40 cm. high, branched from the middle upwards, slender, somewhat tubercled on the lower parts. Branches compound, very slender. Sheaths closely convolute 7–10 mm. long on the stems, very obtuse, subulate-mucronate, coriaceous, light brown, with two deciduous pale-membranous lobes arising from the very obtuse upper end of the persistent portion. Female spikelets terminal and solitary, 5–7 mm. long, 2- or 3-flowered, oblanceolate or cuneate, with long internodes. Spathe sheath-like, reaching to about the middle of the spikelet. Bracts all fertile, 5–6 mm. long, oblong, obtuse, apiculate, cartilaginous, light brown, pale-membranous at the margins, long-decurrent at the base. Perianth 3·5–4 mm. long, trigonous, oblong, narrowed into a stout stipe: outer segments oblong, acute, navicular, cartilaginous,,glabrous: inner segments about as long, oblong-lanceolate, obtuse, membranous. Ovary obovate, dorsally compressed, 1-chambered, with a distinct swelling on one or both sides suggestive of a possibility of dehiscence in the fruiting stage. Styles 3, free, arising from a stout stylopodium.

Cape Province.—PAARL DIV.: Bailey's Peak, 4000 feet alt., *Esterhuysen*, 1621, ♀ (in Bolus Herbarium).

A distinct species, but having the type of perianth possessed by *L. rigidus*, Mast. The lateral swellings on the ovary suggest a dehiscent fruit. They are unusual in this genus, and interesting as possible evidence of a very close relationship between it and *Restio*.

L. Levynsiae, sp. nov.; caulis ramosis gracilibus minute tuberculatis;

vaginis arte convolutis acutis, supra medium membranaceis; spiculis masculis ellipticis in cymas spicatas vel paniculatas dispositis; bracteis elliptico-oblongis acutis; perianthio elliptico; segmentis exterioribus oblongis acutis, lateralibus navicularibus glabris; segmentis interioribus obtusis; spiculis femineis ellipticis multifloris in cymas spicatas dispositis; bracteis oblongis acutis; perianthio trigono; segmentis oblongis obtusis, exterioribus lateralibus navicularibus anguste alatis, interioribus valde longioribus; ovario elliptico trigono; stylis tribus liberis.

Stems about 40 cm. high, moderately branched, wiry, minutely and closely tubercled, with a bronze iridiscence. Sheaths mostly 1·5–2 cm. long, closely convolute; the greater part coriaceous, pale brown and yellow-speckled on the lower half; the upper part acute, mucronate, membranous and deciduous from a truncate base. Male inflorescence a spicate or paniculate cyme 2–5 cm. long. Spathes sheath-like. Spikelets 5–8 mm. long, elliptic. Bracts about 4 mm. long, elliptic-oblong, acute, cartilaginous, pale brown, towards the apex purple-brown. Perianth 3 mm. long, elliptic; outer segments oblong; the lateral navicular, acute, cartilaginous, glabrous; inner segments much shorter, ovate-lanceolate, obtuse, membranous. Female spikelets about 1·5 cm. long, elliptic, many-flowered, 2–5 in a spicate cyme. Spathes sheath-like. Bracts loosely imbricate, 1–1·3 cm. long, oblong, acute, cartilaginous, brown, streaked purple-brown. Perianth about 4·5 mm. long, very shortly stipitate, trigonous: outer segments oblong, obtuse, cartilaginous; the lateral navicular, with a narrow dorsal wing: the inner distinctly longer, oblong, obtuse, membranous. Ovary elliptic, sharply 3-angled. Styles 3, free.

Cape Province.—CERES DIV.: Zwart Ruggens, "Kat Bakkies," east slopes, 4000 feet alt., *Levyns*, 1790, ♂ and ♀, 1845, ♂ and ♀ (type, in Bolus Herbarium).

The affinity is with *L. distichus*, Pillans, from which it is distinguished by a much taller habit of growth, smaller male spikelets and a larger female perianth having the outer lateral segments much less winged and shorter than the inner.

L. Rattrayi, sp. nov.; culmis ramosis gracilibus laevibus; vaginis arte convolutis acuminatis aristatis, marginibus late membranaceis; spiculis masculis cuneato-ellipticis in cymas spictatas vel paniculatas dispositis; bracteis oblongo-lanceolatis acutis papyraceis; perianthio cuneato-oblongo; segmentis oblongis acutis; spiculis femineis bracteisque similibus sed longioribus; perianthio cuneato-oblongo compresso; segmentis exterioribus oblongis, lateralibus navicularibus obtusis; segmentis interioribus aequalibus vel sensim longioribus oblongo-lanceolatis acutis; ovario rotundato compresso uniloculari; stylis duobus brevibus, basi connati.

Stems 50–70 cm. high, moderately branched, wiry in the lower parts

more slender above, smooth, minutely brown-speckled. Sheaths closely convolute, the larger about 2 cm. long excluding the awn, acuminate, aristate, coriaceous, widely membranous at the margins, minutely brown-speckled. Male spikelets one to several in a spicate or paniculate cyme about 1 cm. long, cuneate, elliptic. Bracts very loosely imbricate, 6–8 mm. long, oblong-lanceolate, acute, apiculate, chartaceous, widely membranous at the margins, pale, with the median portion red-brown on the upper half. Perianth distinctly stipitate, 3·5–4·5 mm. long, cuneate-oblong: segments oblong, acute, glabrous; the outer cartilaginous; the lateral navicular; the inner membranous. Anthers 1-celled. Female spikelets resembling the male but 1·5–2 cm. long. Bracts as in the male but 1–1·5 cm. long. Perianth distinctly stipitate, 4–5 mm. long, cuneate-oblong, dorsally compressed: outer segments oblong, cartilaginous; the lateral navicular, obtuse: inner segments equalling or distinctly longer than the outer, oblong-lanceolate, acute, membranous. Ovary sessile, rotundate, compressed, slightly angular on the dorsal surface, 1-chambered. Styles 2, connate at base, diverging, short. Fruit about 3 mm. long, elliptic, flattened on the inner face, rounded on the outer, with compressed lateral margins.

Cape Province.—CALEDON DIV.: Wildepaardeberg, *Stokoe*, 2781, ♀ (type, in Bolus Herbarium).—WORCESTER DIV.: Fonteintjesberg, *Stokoe*, 2782, ♂ (type, in Bolus Herbarium); Brandwacht Mountain, Disa Glen, 5000 feet alt., *Stokoe*, 1961, ♂.—CERES DIV.: Conical Peak, *Stokoe*, 7623, ♀.—PRINCE ALBERT DIV.: Zwartberg, *Stokoe*, 7200, ♀.— VICTORIA EAST DIV.: Hogsback, *Rattray*, 201, ♀.

A very distinct and somewhat anomalous species. It is the first species of *Leptocarpus* with 2 styles to be recorded in South Africa.

L. secundus, sp. nov.; culmis parce ramosis gracilibus tuberculatis; vaginis acutis mucronatis, marginibus superioribus late membranaceis; spiculis masculis oblongis in cymas spicatas dispositis; bracteis oblongo-lanceolatis acutis cartilagineis; perianthio oblongo; segmentis exterioribus oblongo-lanceolatis acutis; segmentis interioribus lanceolatis; spiculis femineis masculinis conformibus 1-floris; bracteis ut in mare; perianthio oblongo; segmentis exterioribus lanceolatis acutis navicularibus; segmentis interioribus brevioribus ovato-lanceolatis obtusis; ovario trigono; stylis tribus.

Stems 30–40 cm. high, moderately branched from below the middle upwards, wiry at base, slender above, studded with closely set, truncate tubercles. Branchlets mostly secund. Sheaths mostly 0·8–1·2 cm. long, closely convolute, acute, obtusely mucronate, coriaceous, purple, with deciduous broad pale-membranous margins. Male spikelets several to many in a spicate cyme, oblong, 4–6 mm. long, 1- or 2-flowered. Spathe about 8 mm. long, sheath-like. Bracts 3–6 mm. long, embracing the

flowers, oblong-lanceolate, acute, cartilaginous, membranous at the apex. Perianth 3·5–4·5 mm. long, oblong, trigonous: outer segments oblong-lanceolate, acute, cartilaginous, glabrous: inner segments slightly shorter, lanceolate, acute, membranous. Female spikelets resembling the male, 1-flowered. Spathe and bracts as in the male. Perianth about 5 mm. long, oblong: outer segments alike, lanceolate, acute, navicular, cartilaginous: inner segments distinctly shorter, ovate-lanceolate, obtuse, membranous. Ovary 3-sided. Styles 3, adjacent at base.

Cape Province.—SWELLENDAM DIV.: south slopes of the Swellendam Mountain, *Esterhuysen*, 4798, ♂ and ♀ (in Bolus Herbarium).

The affinity is with *L. rigidus*, Mast., from which it is distinguished in the female by a much longer perianth and the very acute outer segments distinctly longer than the inner.

THAMNOCHORTUS, *Berg.*

T. acuminatus, sp. nov.; culmis gracilibus minute pubescentibus simplicibus vel ad medium ramis sterilibus; vaginis attenuatis membranaceis; spiculis masculis ellipticis in cymas paniculatas dispositis; bracteis lanceolatis acutissimis membranaceis; perianthio elliptico membranaceo; segmentis exterioribus oblongis, lateralibus paulum carinatis; segmentis interioribus lanceolatis; spiculis femineis obovatis solitariis vel geminatis; bracteis lanceolatis attenuatis membranaceis; perianthio suborbiculari, supra medium latissimo; segmentis exterioribus lineari-lanceolatis acutis, lateralibus valde alatis; segmentis interioribus paulum brevioribus lanceolatis; ovario elliptico; stylo solitario.

Stems about 30 cm. high, slender, minutely velvety pubescent, simple except for much divided, sterile branches about the middle. Sheaths mostly 6–7 cm. long, linear-oblong, attenuate, membranous, closely convolute at the base, parting from the stem upwards. Male spikelets about 1·5 cm. long, elliptic, erect or cernuous, many in a paniculate cyme. Bracts about 1·2 cm. long, very loosely imbricate, lanceolate, very acute, membranous, red-brown, with wide, pale margins. Perianth 5 mm. long, elliptic, membranous: outer segments oblong, acute; the lateral navicular, slightly carinate: inner segments slightly longer, lanceolate, acute. Female spikelets solitary or geminate, 2–2·5 cm. long, obovate. Bracts very loosely imbricate, 1·5–2 cm. long, lanceolate, attenuate, membranous, red-brown, pale at the margins. Perianth 6–7 mm. long, 7 mm. wide, stipitate, suborbicular, widest above the middle: outer segments linear-lanceolate, acute; the lateral navicular, diverging from the middle upwards, with a membranous wing 2·5 mm. wide shortly above the middle, thence narrowing

towards the base and apex: inner segments slightly shorter, lanceolate, acute. Ovary elliptic. Style slender.

Cape Province.—CERES DIV.: Roodeberg, 6500 feet alt., *Esterhuysen*, 1505, ♂, 1506, ♀ (in Bolus Herbarium).

The affinity of this species is with *T. fruticosus*, Berg., from which it chiefly differs by the larger female spikelets with longer bracts, and by the female perianth being widest above the middle and having the outer lateral segments diverging slightly from about the middle.

T. papyraceus, sp. nov.; culmis simplicibus gracilibus; vaginis supra medium membranaceis valde laceratisque; spiculis masculis ellipticis in paniculatas dispositis; bracteis papyraceis ovato-lanceolatis acutis; perianthio elliptico valde compresso; segmentis exterioribus oblongis acutis, lateralibus carinatis; segmentis interioribus obtusis; spiculis femineis ellipticis, 1–3 in cymam spicatam vel paniculatam dispositis; bracteis oblongo-lanceolatis acutissimis papyraceis; perianthio late ovato-orbiculari; segmentis exterioribus lanceolatis acutis, lateralibus navicularibus valde alatis, anterioribus paulum brevioribus fere planis; segmentis interioribus ovato-lanceolatis acutis; ovario rotundato; stylo solitario.

Stems 30–50 cm. high, simple, wiry, smooth. Sheaths 6–10 cm. long, closely convolute and firm in the lower half, loosely convolute and papery in the upper half, considerably lacerate above the middle, buff coloured, speckled with red-brown. Male spikelets 1–1·5 cm. long, elliptic, cernuous, many in a panicle 4–6 cm. long. Bracts loosely imbricate, papery, mostly 8–9 mm. long, ovate-lanceolate, acute, mucronulate, pale, tinted red-brown towards the apex. Perianth about 4·5 mm. long, elliptic, much compressed: outer segments oblong, acute, cartilaginous; the lateral navicular, carinate: inner segments obtuse, membranous. Female spikelets 1–3 in a spicate or paniculate cyme, 2–2·5 cm. long, elliptic. Bracts loosely imbricate, about 1·5 cm. long, oblong-lanceolate, acute, papery, pale. Perianth 6–7 mm. long, 5·5–6 mm. wide at the middle, broadly ovate-orbicular: outer segments lanceolate, acute; the lateral navicular, apiculate, distinctly longer than all the others, with a pale-membranous wing about 1·75 mm. wide; the anterior slightly shorter, almost flat: inner segments slightly shorter than the anterior, ovate-lanceolate, acute, membranous. Ovary rotundate, scabrid, thickened at the edges, surmounted by a solitary style.

Cape Province.—PRINCE ALBERT DIV.: mountains at Seven Weeks Poort, 5000–7000 feet alt., *Stokoe*, in Bolus Herbarium, 19091, ♂ and ♀ (type), *Andreae*, 1247, ♀.

The affinity is with *T. Stokoei*, Pillans, from which it is distinguished by the pale bracts and much larger, differently shaped female perianth.

T. pulcher, sp. nov.; culmis simplicibus gracilibus laevibus; vaginis acutis aristatis cartilagineis, marginibus membranaceis; spiculis masculis

ellipticis vel rotundatis 2–4 in cymam paniculatam dispositis; bracteis elliptico-oblongis acutis aristatis; perianthio oblongo cartilagineo; segmentis oblongis acutis, exterioribus lateralibus navicularibus valde carinatis; spiculis femineis solitariis vel geminatis ellipticis; bracteis ut in mare; perianthio elliptico; segmentis exterioribus oblongis obtusis, lateralibus anguste alatis; segmentis interioribus lanceolatis obtusis; ovario suborbiculari; stylo solitario.

Stems 30–40 cm. high, simple, wiry, smooth. Sheaths mostly about 2·5 cm. long, closely convolute, acute, aristate, cartilaginous, ribbed longitudinally, membranous at the upper margin. Male spikelets cernuous, usually 2–4 in a panicle, 1·5–2 cm. long, elliptic or rotundate, brown. Spathe sheath-like. Bracts loosely imbricate 1–1·5 cm. long, elliptic-oblong, acute, aristate. Perianth 5–6 mm. long, oblong, cartilaginous: segments oblong, acute; the outer lateral navicular, amply carinate. Female spikelets solitary or geminate, about 2 cm. long, elliptic, cuneate at base. Spathe sheath-like, reaching to the top of the spikelet. Bracts as in the male. Perianth stipitate, 6–7 mm. long, elliptic, cartilaginous: outer segments oblong, acute; the lateral navicular, with a narrow, transparent wing; the inner slightly longer, lanceolate, obtuse. Ovary suborbicular, surmounted by a solitary style.

Cape Province.—Caledon Div.: Hottentots Holland Range, Landdrost Kop, 4000 feet alt., *Stokoe*, 4015, ♂ and ♀, *Esterhuysen*, 3593, ♂ and ♀ (type, in Bolus Herbarium).

A distinct species with spikelets unlike those of any other in the genus.

STABEROHA, *Kunth.*

S. remota, sp. nov.; culmis simplicibus gracilibus; vaginis acuminatis aristatis; spiculis masculis rotundatis cernuis in cymas paniculatas dispositis; bracteis ovato-lanceolatis acutis; perianthio elliptico membranaceo; segmentis exterioribus oblanceolatis acutis, lateralibus carinatis; segmentis interioribus paulum longioribus ellipticis obtusis; spiculis femineis solitariis ellipticis; bracteis ovato-lanceolatis acutis; perianthio elliptico; segmentis oblongis obtusis cartilagineis, exterioribus lateralibus carinatis; ovario elliptico, apice duro; stylis duobus, basi connatis.

Stems about 30 cm. high, simple, wiry, slightly tubercled. Sheaths closely convolute, acuminate, aristate, coriaceous and red-brown in the lower half, the upper half pale-membranous and deciduous. Male spikelets about 1 cm. long, rotundate, cernuous, several or many in a paniculate cyme. Bracts loosely imbricate, 8–9 mm. long, ovate-lanceolate, acute, chartaceous, red-brown, with pale-membranous margins. Perianth 4 mm. long, elliptic, membranous, brown: outer segments oblanceolate, acute;

the lateral navicular, carinate: inner segments slightly longer, elliptic, obtuse. Female spikelets solitary, about 2 cm. long, elliptic. Spathe sheath-like, reaching to or slightly above the top of the spikelet. Bracts about 1·5 cm. long, loosely imbricate, ovate-lanceolate, acute, cartilaginous, red-brown, pale at the margins. Perianth sessile, 3·5 mm. long, elliptic, narrowed at the base: segments oblong, obtuse, cartilaginous; the outer lateral navicular, carinate. Ovary elliptic, with a horny cap. Styles 2, connate at base.

Cape Province.—CERES DIV.: Roodeberg, 6000 feet alt., *Esterhuysen*, 1492, ♂, 1493, ♀ (in Bolus Herbarium).

The affinity of this species is with *S. Banksii*, Pillans, but it is distinguished by its differently shaped female inflorescence, perianth, and ovary.

HYPOLAENA, *R. Br.*

H. Stokoei, sp. nov.; culmis ramosissimis gracilibus paulum compressis; vaginis arte convolutis acutis aristatis; spiculis masculis 1-floris 1–3 in cymam spicatam dispositis; bracteis lanceolatis acutis; perianthio plerumque nudo oblongo; segmentis exterioribus oblongo-lanceolatis acutis paulum carinatis; segmentis interioribus oblongo-lanceolatis obtusis; spiculis femineis fusiformibus 1-floris solitariis vel in cymam spicatam dispositis; bracteis lanceolatis apiculatis vel aristatis membranaceis perianthium excedentibus; perianthio oblongo tereti; segmentis oblongo-lanceolatis acutis cartilagineis; ovario apice paulum tuberculato; stylis duobus liberis; fructu tuberculato.

Stems 30–60 cm. long, ascending or decumbent, much branched, somewhat compressed, slender in the lower parts, filiform in the upper, wrinkled. Sheaths tightly convolute, mostly 1–1·5 cm. long at the middle of the plant, acute, aristate, cartilaginous, membranous at the upper margin. Male spikelets about 2 mm. long, 1–3 in spicate cymes arising from the uppermost 1–3 nodes of the stems, 1-flowered. Spathe lanceolate, aristate, without the awn slightly exceeding the spikelet. Bract equalling the perianth, lanceolate, acute, membranous, often absent. Perianth 1·75–2·5 mm. long, for the most part exposed, oblong, slightly compressed: outer segments oblong-lanceolate, acute, slightly carinate, glabrous: inner segments slightly shorter, oblong-lanceolate, obtuse, membranous. Female spikelets solitary at the second or third node, or at both, from the tip of the stem, 7–8 mm. long, fusiform, terete, 1-flowered. Spathe as in the male. Bracts several, lanceolate, apiculate or aristate, membranous, distinctly exceeding the perianth. Perianth 3–4 mm. long, oblong, terete: segments oblong-lanceolate, acute, dorsally rounded, cartilaginous, glabrous; the inner distinctly the shorter. Ovary smooth, the cap becoming tubercled with

development. Styles 2, distinct. Fruit about 2·5 mm. long, rotundate or obovate, tubercled on the summit, elsewhere rugose.

Cape Province.—CALEDON DIV.: Hottentots Holland Mountains, *Stokoe*, 7620, ♂, 7621, ♀ (in Bolus Herbarium).

The affinity of this species is with *H. diffusa*, Mast. and *H. tabularis*, Pillans, but it is distinguished from both by its compressed stems, the absence of tubercles from the stems, and by the differently shaped perianth-segments in the female.

HYPODISCUS, *Nees.*

H. alternans, sp. nov.; culmis simplicibus gracilibus; vaginis persistentibus obtusis aristatis; spiculis masculis ellipticis alternis in cymas spicatas dispositis; bracteis ellipticis acutis mucronatis; perianthio elliptico-oblongo compressissimo; segmentis exterioribus oblongo-linearibus acutis, lateralibus carinatis; segmentis interioribus oblongo-lanceolatis obtusis; spiculis femineis lineari-oblongis 2–4 in cymam spicatam dispositis; bracteis oblongis acutis; perianthio sessili; segmentis lanceolatis membranaceis, exterioribus acuminatis, interioribus sensim brevioribus obtusis. Ovario superne disco carunculato donato; stylis ad basin connatis.

Stems tufted, 30–55 cm. high, slender, simple, minutely wrinkled. Sheaths 2 or 3 above the basal, mostly 1·5–2·5 cm. long, persistent, obtuse, with the midrib excurrent in an awn, coriaceous, red-brown, minutely speckled yellow. Male spikelets 8–10 mm. long, elliptic, several or many arranged alternately in a spicate cyme 2–3 cm. long. Spathe 7–10 mm. long, ovate-elliptic, acute, aristate, persistent, coloured like the sheaths. Bracts loosely imbricate, 7–8 mm. long, elliptic, acute, mucronate, coriaceous, reddish. Perianth almost as long as the bract, elliptic-oblong, much compressed, membranous: outer segments oblong-linear, acute; the lateral navicular, carinate: inner segments slightly shorter, oblong-lanceolate, obtuse. Female spikelets 2–4 in a spicate cyme, linear-oblong, 8–10 mm. long. Spathes similar to those of the male plant. Bracts loosely imbricate, 6–8 mm. long including the mucro, oblong, acute, cartilaginous. Perianth sessile, about 1·5 mm. long, membranous: segments lanceolate; the outer acuminate; the inner distinctly shorter, obtuse. Ovary crowned with 2 adjacent circles of tubercles. Styles connate at base.

Cape Province.—CALEDON DIV.: between Palmiet River and Kleinmond, *Stokoe*, 1342, ♂ and ♀ (in Bolus Herbarium).

The affinity of this species is with *H. binatus*, Mast. and *H. synchroolepis*, Mast., but it differs from both in having narrower male and female spikelets and differences in floral characters.

H. paludosus, sp. nov.; culmis gracilibus laevibus paulum curvis; vaginis 1–2 supra basin acutis aristatis coriaceis, marginibus superioribus membranaceis; spiculis masculis solitariis rotundatis; bracteis arte imbricatis oblongo-ellipticis acutis mucronulatis, cartilagineis, marginibus superioribus denticulatis; perianthio stipitato elliptico membranaceo; segmentis exterioribus oblongis acutis, lateralibus navicularibus; segmentis interioribus paulum brevioribus elliptico-oblongis acutis.

Stems 20–25 cm. high, slender, terete, sometimes compressed when dried, often somewhat curved, smooth. Sheaths 1 or 2 above the basal, loosely convolute, acute, aristate, coriaceous, straw coloured, pale-membranous at the upper margin. Male spikelets solitary, 7–10 mm. long, rotundate. Bracts closely imbricate, 6 mm. long, oblong-elliptic, acute, mucronulate, cartilaginous, red, pale-membranous and denticulate at the upper margin. Perianth 4·5–5 mm. long, stipitate, elliptic, membranous: outer segments oblong, acute; the lateral navicular: inner segments slightly shorter, elliptic-oblong, acute. The female is unknown.

Cape Province.—Cape Div.: middle north-east face of the Steenberg, on wet soil, *Pillans*, 4179, ♂ (in Bolus Herbarium).

The affinity of this species is with *H. albo-aristatus*, Mast. and *H. binatus*, Mast., being distinguished from the former by wider spikelets and the absence of a long mucro on the bracts, and from the latter by larger spikelets and narrower bracts.

H. sulcatus, sp. nov.; culmis rigidis sulcatis; vaginis obtusis mucronatis coriaceis sulcatis; spiculis masculis rotundatis in cymas paniculatas dispositis; bracteis late ovatis acuminatis; perianthio elliptico membranaceo; segmentis exterioribus oblongis, lateralibus navicularibus; segmentis interioribus longioribus obtusis; spiculis femineis solitariis lineari-lanceolatis 1-floris; bracteis ovato-lanceolatis attenuatis; perianthio membranaceo; segmentis exterioribus obovatis obtusissimis; segmentis interioribus conspicue brevioribus ellipticis; ovario cylindrico, apice duro; stylis duobus ad medium connatis.

Stems crowded on creeping rhizomes, 20–40 cm. high, 2 mm. thick at the middle, conspicuously sulcate, often curved several times. Sheaths 2 or 3 above the base, tightly convolute, obtuse, mucronate, coriaceous, sulcate. Male spikelets 5–7 mm. long, rotundate, crowded in paniculate cymes 1–1·5 cm. long. Bracts loosely imbricate, 4–5 mm. long, broadly ovate, acuminate, cartilaginous, reddish, with broad, pale-membranous margins. Perianth about 4 mm. long, elliptic, membranous: outer segments oblong, acute; the lateral navicular: inner segments distinctly longer, obovate-oblong, obtuse. Female spikelets solitary, 1-flowered, about 2 cm. long, linear-lanceolate. Bracts tightly convolute, 1·8–2 cm. long, ovate-lanceolate, attenuate, cartilaginous, red-brown. Perianth

sessile, about 2·5 mm. long, terete, pale-membranous: outer segments obovate, very obtuse: inner segments about half as long, elliptic. Ovary about twice as long as the perianth, topped with a hard, rounded cap. Styles 2, long and slender, united almost half their length. Fruit about 1·2 cm. long, terete, widest above the middle, woody, smooth.

Cape Province.—WORCESTER DIV.: Bonteberg, "Gouronna," *Esterhuysen*, 3726, ♂ and ♀ (type, in Bolus Herbarium).—LAINGSBURG DIV.: Tweedside, 3200 feet alt., *Compton*, 3151, ♂.

A distinct species which may be placed nearest *H. striatus*, Mast., from which it differs in its much stouter stems and larger and differently shaped spikelets in both sexes.

WILLDENOWIA, *Thunb.*

W. Stokoei, sp. nov.; culmis simplicibus vel paulum ramosis rigidis laevibus; vaginis aristatis; inflorescentia mascula dense paniculato-cymosa; bracteis linearibus attenuatis; perianthio membranaceo; segmentis exterioribus acicularibus; segmentis interioribus oblanceolatis; spiculis femineis 1–2-floris, in cymam spicatam dispositis; bracteis ovatis mucronatis; perianthio sessili membranaceo; segmentis rotundatis emarginatis subaequantibus; ovario obconico; stylis duobus ad basin connatis.

Stems shortly spaced on creeping rhizomes, simple or rarely with a single branch, 30–60 cm. high, 2–2·5 mm. thick at the middle, smooth. Sheaths about 2·5 cm. long (including the membranous portion), loosely convolute, coriaceous, membranous above the middle, acute, aristate. Male inflorescence 2·5–5 cm. long, a dense paniculate cyme. Spathes sheath-like but shorter. Bracts 6–8 mm. long, linear, attenuate, membranous, erect-spreading; the outer acicular; the inner slightly shorter or equal, oblanceolate. Female inflorescence 4–5 cm. long, a compact, spicate cyme, containing 2–4 spikelets each with 1 or 2 flowers. Spathes about 3 cm. long, sheath-like but only membranous at the margin above the middle. Spathellae 1–1·5 cm. long, ovate-lanceolate, acuminate, cartilaginous. Bracts 6–10 mm. long, ovate, mucronate, cartilaginous, widely membranous at the sides. Perianth sessile, terete, about 4 mm. long, membranous: segments about equal in size, rotundate, emarginate, with a small mucro in the angle. Ovary obconic, with a broadly conical, horny cap. Styles 2, slender, shortly united at base. Fruit rotundate, conspicuously pitted.

Cape Province.—CERES DIV.: summit of the Roodeberg, 7000 feet alt., *Esterhuysen*, 1489, ♀, 1490, ♂ (type, in Bolus Herbarium).—PRINCE ALBERT

Div.: mountain at Seven Weeks Poort, 6800 feet alt., *Stokoe*, in Bolus Herbarium, 22643, ♂ and ♀.

A distinct species. The perianth of the female plant resembles that of *W. teres*, Thunb., but it is not stipitate as in that species, and the stems are very different.

TRANSACTIONS

OF THE

ROYAL SOCIETY OF SOUTH AFRICA.

VOL. XXIX.

MINUTES OF PROCEEDINGS.

Report of the Hon. General Secretary for 1936.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the undermentioned papers were read:—

1. "The Relationship between Winter Rainfall and Barometric Pressure, Barometric Tendency, and Wind Direction at Cape Town," by H. E. Morrison and J. T. Morrison.
2. "A Study of the Aspiration Psychrometer," by A. F. Spilhaus (communicated by A. Brown).
3. "The Archaeology of the Florisbad Deposits," by T. F. Dreyer.
4. "The Archaeological Succession of the Natural Deposits at Plettenberg Bay and Mossel Bay," by T. F. Dreyer.
5. "The Chromosome Numbers in the Genus *Berberis*," by M. H. Giffen.
6. "Contribution to the Study of *Dichapetalum cymosum* and the Ecology of the Transvaal Veld," by A. C. Leèmann.
7. "South African Native Ceramics," by P. W. Laidler.
8. "Some Observations on *Opuntia* Used as a Larvicide," by F. G. Cawston.
9. "History of the Ba-ga-Malete of Ramoutsa," by Vivien Ellenberger (communicated by A. J. H. Goodwin).
10. "Acculturation among the BaKxatla," by I. Schapera.
11. "Some Diatoms from the Victoria Falls," by Florence Rich (communicated by Miss E. L. Stephens).
12. "Use of Serum as an Accessory Medium in Tissue Culture," by W. S. S. Ladell.

13. "A Revised Simple Technique for the Frog Test," by H. ZWARENSTEIN.

14. "The Pancreas and Blood Inorganic Phosphorus," by V. SCHRIRE and H. ZWARENSTEIN.

15. "Notes on the Genus *Stoebe*," by Mrs. M. R. LEVYNS.

16. "Fishes New to South Africa," by J. L. B. SMITH.

17. "Mercurous Perchlorate and the Monovalent Mercurous Ion," by E. NEWBERY.

18. "Rock Engravings in the Vaal River Basin," by C. VAN RIET LOWE.

19. "Studies in the Inorganic Metabolism of the Kelsey and Gaviota Plums.—I. Potassium," by L. N. COHEN.

20. "Women's Initiation among the Mpondo," by J. S. GRIFFITHS (communicated by A. J. H. GOODWIN).

21. "The Mpondo Regimental System," by A. J. H. GOODWIN.

22. "Young's Modulus for Steel Surveying Bands," by J. A. GILMORE.

23. "Some Studies of 50 Cycle Wave-Forms in Insulation Testing," by N. H. ROBERTS (communicated by E. NEWBERY).

24. "A Device for the Superposition and Simultaneous Delineation of Two Wave-Forms on a Single Cathode Ray Oscillograph Screen," by N. H. ROBERTS (communicated by E. NEWBERY).

25. "Rock Engravings near Beaufort West," by W. G. SHARPLES.

26. "Studies in South African Algae.—I. Hydrodictyon in South Africa," by M. A. POCOCK.

27. "The External Sexual Characters of South African Harvest Spiders," by R. F. LAWRENCE.

28. "Some French Historical Sources used by Sir Walter Scott.—I. Quentin Durward," by D. INSKIP (communicated by A. J. H. GOODWIN).

29. "Some Notes on the Political Organisation of Certain Xhosa-speaking Tribes in the Transkeian Territories," by G. P. LESTRADE (communicated by I. SCHAPERA).

30. "Anomalous Secondary Thickening in Osteospermum," by R. S ADAMSON.

31. "The Effects of Oil-Sprays on the Transpiration of Peach Twigs," by G. D. B. DE VILLIERS and S. M. NAUDÈ.

32. "Studies in Deciduous Fruit.—IV. On the Distribution of Nitrogenous Fractions in the Pulp of the Kelsey Plum (*Prunus salicina*)," by I. DONEN.

33. "Studies in Deciduous Fruit.—V. Preliminary Observations on the Relationship between Nitrogenous Metabolism and Internal Breakdown of Kelsey Plums in Cold Store," by I. DONEN.

34. "A Middle Stone Age Site at Tygerberg, near Prince Albert," by W. E. SHARPLES.

35. "The South African Inter-Tidal Zone in its Relation to Ocean Currents.—I. A Temperate Indian Ocean Shore," by T. A. Stephenson, A. Stephenson, and C. A. du Toit.

36. "Experimental Induction of Ovulation," by H. Zwarenstein.

37. "Combined Oscillographic and Camera Studies of Lightning," by B. F. J. Schonland, D. B. Hodges, and H. Collens.

At the Anniversary Meeting of the Society held on March 18, 1936, the President, Dr. A. W. Rogers, delivered an address on the "Superficial Deposits of the Kalahari."

At the Ordinary Meeting of the Society held on August 19, 1936, Mr. J. A. Gilmore gave a demonstration of "Extensometer for Use on Steel Bands of Small Cross-section."

Vol. XXIII, part 4, and Vol. XXIV, parts 1 and 2, of the Society's Transactions have been issued during the year.

Alexander Galloway, S. Meiring Naudè, James Leonard Brierly Smith, Noel James Gillies Smith, and H. Zwarenstein were elected Fellows of the Society in 1935.

At the end of 1936 the number of Fellows was 81; Members, 122. During the year five Members resigned and the names of one Fellow and two Members were struck off the list. Eight new Members were elected during the year, and one former Member rejoined the Society.

The deaths during the year of Dr. A. Marius Wilson, Mr. F. B. Parkinson, and Sir Arnold Theiler are recorded with regret.

At the Ordinary Meeting of the Society held on August 19, a resolution was passed expressing the deep regret of the Society at the death of Sir Arnold Theiler, Honorary Fellow of the Society.

The thanks of the Council are due to the Minister for Education and the Government for the Grant of £400 for the year 1936–37; the Council's thanks are due, too, to the Research Grant Board for a Carnegie Grant of £30 towards printing two papers by J. L. B. Smith—"Two Interesting New Fishes from South Africa" and "New Gobioid and Cyprinid Fishes from South Africa," and to the Minister for Education and the Government of Bechuanaland Protectorate for a Grant of £30 towards printing a paper by V. E. Ellenberger—"History of the BaTlokwa of Bechuanaland Protectorate."

The following gifts were received by the Library during the year:—

From Salzburger Hochschulwochen, Konrad Millers Lebenswerk; from Dr. W. J. Hall, The Genus Tachardina (*Lacciferidae, coccidae*) in Southern Africa, by the donor; from Universidad Nacional de Mexica, Universidad;

from Department of Agriculture, Ottawa, Report of the Minister . . . for Year ended March 31, 1935; from Dr. Gerhard Nilsson, Stockholm, Kometen, Erster und Höherer Klasse, by the donor; from Accademia Nacional de Ciencias Antonio Alzate, Mexico, General Author and Subject Index to vols. 1–52, 1887–1931, of Memorias y Revista; from Citrus Experiment Station, Mazoe, Annual Report, 1934; from Svenska Botaniska Föreningen, Stockholm, General Register til Svensk Botanisk Tidskrift, vols. 1–20; from Internationalen Aerologischen Kommission, Berlin, Uber die Durchführung von aerologischen Flugzeugaufstiegen in den verschiedenen Ländern; from Norman Lockyer Observatory, Sidmouth, Devon, Reprints; from Research Grant Board, Johannesburg, Report, 1918–35; from Department of Mines, Pretoria, The Mineral Resources of South Africa, 1936; from Department of Mines, South-West Africa, Memoirs, Nos. 1–2; from the Field Naturalists Section, Royal Society of S. Australia, National Park, Morialta and Waterfall Gully Reserves . . . an Account of their Natural History; from U.S. Department of Agriculture Library, Bibliographical Contributions, 26, 27, 29, 1935–36; from Russell H. Anderson, Museum of Science and Industry, Chicago, Grain Drills through 39 Centuries, by the donor; from Svenska Växtgeografiska Sallskapet, Acta Phytogeographica Suecica: VIII, Granskär och Fiby Urskog, by Rutger Sernander; from the Publishers, Dresden, Photographie und Forschung, for 1936; from the Meijikai, Tokyo, What is Nippon Kokutai?, Nos. 3–11, 1936, by Chigaku Tanaka; from Mrs. Benjamin, the following numbers of Transactions of the Royal Society of South Africa, from the library of the late Mr. Justice Benjamin: vol. 3, pt. 1; 10, pt. 2; 12, pt. 1; 15; 14, pts. 2–4; 16, pts. 1–4; 17, pts. 1–4; 18, pts. 1, 2, 4; 19, pts. 1–4; from the Government Stationery Office, Cape Town, Report of the Marine Biologist, 1896, 1898, Marine Biological Reports, Nos. 3–4, 1916, 1918; from Dr. H. G. Fourcade, Reports of the Meteorological Commission, Cape of Good Hope, for 1875–1902 (missing 1876, 1897), Results for 1876–79.

The following exchange has been discontinued:—Brooklyn Institute of Arts and Sciences, Brooklyn, N.Y.

New exchanges have been arranged with the following institutions:—Sociedad de Biologia de Montevideo; University of Arizona, Tucson; Committee for Natural History Research in Bohemia, Prague; Magyar Nemzeti Muzeum, Budapest; National Botanic Gardens, Kirstenbosch; U.S. Geology Survey, Washington; Sociètè Scientifique de Skoplje, Jugo-Slavia.

The following back numbers have been obtained during the year as gifts or by exchange:—Australia, Council for Scientific and Industrial Research, Journal, vol. 1, 1927–vol. 5, 1933; Minnesota Academy of

Sciences, Bulletin, vol. 1, Nos. 1–3, 5–6; vol. 2, Nos. 1–5; vol. 5, Nos. 2–3; Occasional Papers, vol. 1, No. 1; Chemical, Metallurgical, and Mining Society of South Africa, Journal, vols. 2, 3, 8 (6, 7); 14 (4); 13 (9, 12); 21 (2); 24 (7–10); 25 (1, 4–7, 9–12); 26; 27 (1–7, 9–11); 28 (1–3–5, 8); 29 (3); 30 (3); 31 (3–4); 32 (3–4, 7, 10); 33 (2–4, 6, 8, 12); 34 (8); 35 (2, 4); Reischsamt f. Wetterdienst. (formerly Preussische Meteorologische Institutè): Abhandlungen, Bd. 7, Nos. 1–2, 1920; Bd. 8, No. 12, 1926; Bericht über die Tätigkeit, 1914–19; Sociedade de Geografia de Lisboa, Boletim, tome 20 (1–8, 11–12); 21 (1–3, 6–7); 22 (1–6); 39; 40 (1–9); Australian Journal of Experimental Biology and Medical Science, vol. 2, No. 3; vol. 5, No. 4; Sociètè des Naturalistes, Moscow, Bulletin, Nos. 1–4 (1909), No. 4 (1913); Geological Survey, Ottawa, Memoirs, Nos. 12, 18, 25–26, 31, 42, 45–46, 62, 86, 91, 106, 113, 120, 123–129, 131, 133–146, 150–165, 167–180; Summary Reports: 1907, 1919 (D.E.F.G.), 1920 (A.C.D.E.), 1921 (B.C.D.E.), 1922 (B), 1923 (A.B.C.), 1924 (C), 1926 (A), 1927 (A.C.), 1928 (A.B.C.), 1929 (A.B.C.), 1930 (A.B.C.D.), 1931 (A.B.C.D.), 1932 (B.C.D.), 1933 (A.B.C.D.); Museum Bulletin, Nos. 6, 9, 16, 19, 29 to date (excepting Nos. 41, 43, 65, 72); Economic Geology Series, Nos. 2–13; Gesellschaft der Wissenschaften, Göttingen, Geschäftliche mitteilungen, Heft 1, 1912.

The Library is being increasingly used by Members and by staff and students of the University of Cape Town.

Owing to delays by the firm responsible for the Society's binding, only 144 volumes were bound during the year.

During the year the dispatch of cards to the Regional Bureau for South Africa of the International Catalogue of Scientific Literature was discontinued.

A. J. H. Goodwin,
Hon. General Secretary.

Report of the Hon. Treasurer for 1936.

The estimate of Liabilities includes the Life Fund Provision, and also sums for which the Society is liable in respect of printing now ordered but not payable till 1937.

The excess of Assets over Liabilities has dropped from £598, 12s. 9d. to £332, 3s. 7d. This is due to three main reasons. An amount of £156, 19s. 3d. from the balance of 1935 has been placed in the Life Fund. The estimated cost of printing put in hand during 1936 is taken as a Liability of the funds of 1936. No credit has been given for arrears of subscriptions or sales of publications.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR, JANUARY 1, 1936, TO JANUARY 2, 1937.

DR.

	£ s. d.	£ s. d.
Bank Balance, January 1, 1936		51 9 1
Subscriptions:		
1934 and earlier...	7 0 0	
1935	11 0 0	
1936 Fellows	64 0 0	
1936 Town Members...	56 0 0	
1936 Country Members	61 0 0	
1936 Life Subscriptions	297 10 0	
1936 Entrance Fees	6 0 0	
Advance payments	1 0 0	
		503 11 0
Sale of publications		58 12 8
Sale of Extra Reprints		11 8 2
Commissions received		1 19 9
Grants:		
Union Government	400 0 0	
Carnegie Corporation	30 0 0	
Bechuanaland Protectorate	30 0 0	
		460 0 0
Interest:		
P.O. Savings Bank	3 15 6	
Cape of Good Hope Savings Bank ...	11 11 10	
Standard Bank Savings Bank	0 10 6	
		15 17 10
		£1102 18 6

CR.

	£ s. d.	£ s. d.
Neill's Account:		
Printing	357 17 5	
Postages, cost of drafts, etc.	20 10 5	
Cost of extra reprints	5 1 3	
		383 9 1
Local Printing Account		48 0 0
Binding		33 6 3
Clerical Assistance		48 0 0
Postages and Petty Cash...		32 11 0
Commission and Bank Charges		4 16 11
Rent of Rooms, etc.:		
University of Cape Town...	36 0 0	
S.A. Association	4 4 0	
Caretaker	2 2 0	
		42 6 0
Insurance:		
Books at Jagger Library	0 15 0	
Volumes with Neill	1 5 0	
		2 0 0
Miscellaneous Purchases		4 13 0
Credited to P.O. Savings Bank:		
Paid in	167 10 0	
Interest added	3 15 6	
		171 5 6
Credited to Cape of Good Hope Savings Bank:		
Paid in	47 0 0	
Interest added	11 11 10	
		58 11 10
Credited to Standard Bank Savings Account	250 0 0	
Interest added	0 10 6	
		250 10 6
Bank Balance, December 31, 1936...		23 8 5
		£1102 18 6

ASSETS AND LIABILITIES AT JANUARY 2, 1937.

Assets.*	£	s.	d.	Liabilities.	£	s.	d.
Current Balance	23	8	5	Life Fund	384	1	1
Cape of Good Hope Savings Bank Balance	384	1	1	Binding Allowance unspent	41	13	9
Post Office Savings Bank Balance	323	0	6	Cost of Vol. XXIV, Part 3	114	0	0
Standard Bank Savings Account Balance	271	8	5	Cost of Vol. XXIV, Part 4 (Estimate)	130	0	0
				Excess of Assets over Liabilities	332	3	7
	£1001	18	5		£1001	18	5

* Exclusive of value of Library, Publications of the Society in stock and other properties.

ALEXANDER BROWN, Hon. Treasurer.

We hereby certify that we have examined the above accounts of Revenue and Expenditure and of Assets and Liabilities, with the books, vouchers, and other documents relating thereto, and that in our opinion these accounts set forth a correct statement of the affairs of the Society.

J. W. C. GUNN.
B. J. RYRIE.

The total of the Life Fund is made up of:—

(1) £156, 19s. 3d. from funds available at the end of 1935.

(2) The Life Subscriptions received during 1936 less the amounts corresponding to one annual subscription of each contributor.

(3) The Entrance Fees received during 1936.

In subsequent years it is proposed to use for the purposes of current expenditure in any year the following sums taken from the Life Fund:—

(1) One tenth of the total of the Fund at the end of the previous year.

(2) The interest accrued to the Fund during the previous year.

ALEXANDER BROWN,
Hon. Treasurer.

ANNIVERSARY MEETING.

The Anniversary Meeting of the Society was held on Wednesday, March 17, 1937, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The reports of the Hon. General Secretary and the Hon. Treasurer for the year 1936 were circulated and passed.

The following were elected as Officers and Members of Council for the year 1937:—President, L. CRAWFORD; Hon. Treasurer, A. BROWN; Hon. General Secretary, A. J. H. GOODWIN; Hon. Editor of Transactions, R. S. ADAMSON; Hon. Librarian, E. NEWBERY; Members, E. L. GILL, J. JACKSON, R. F. LAWRENCE, S. M. NAUDÉ, A. PIJPER, B. J. RYRIE, B. F. SCHONLAND, J. L. B. SMITH, R. B. YOUNG.

ORDINARY MEETING.

The Anniversary Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Meeting held on Wednesday, October 21, 1936, were confirmed.

R. A. DART was admitted to Fellowship of the Society.

The congratulations of the Society were extended to K. H. BARNARD on the occasion of his selection by the South African Biological Society for the receipt of the Senior Scott Medal for Scientific Research in South Africa.

The following were proposed for Membership of the Society:—LESTER C. KING, proposed by A. L. HALL, seconded by A. W. ROGERS; J. H. NEETHLING, proposed by C. W. MALLY, seconded by L. VERWOERD; H.

SANDON, proposed by R. S. ADAMSON, seconded by E. L. STEPHENS; J. F. SCHOFIELD, proposed by A. J. H. GOODWIN, seconded by I. SCHAPERA.

Communications:—

"Some Characteristics of Bulinus and Physopsis," by F. G. CAWSTON.

Considerable variation is observed in several species of *Bulinus* so that the various shells may resemble one another very closely. *Physopsis africana* Krauss is readily distinguished by its relatively constant columella. It does not adhere so firmly to floating vegetation as allied shells, but, unlike the operculated shells, is a favourite food for ducks.

"Studies of South African Seaweed Vegetation.—I. West Coast from Lambert's Bay to Cape Point," by W. E. ISAAC.

"The Climate and Stone Implements of Rooikop," by J. C. SMUTS (communicated by C. VAN RIET LOWE).

"Past Climates and Pre Stellenbosch Stone Implements of Rietvlei (Pretoria), and Benoni," by J. C. SMUTS (communicated by C. VAN RIET LOWE).

"Contributions to our Knowledge of Freshwater Algae of Africa.—12. Algae from the Belfast Pan, Transvaal," by F. E. FRITSCH and F. RICH (communicated by E. L. STEPHENS).

"The Florisbad Skull and Brain Cast," by M. R. DRENNAN.

"Contribution to our Knowledge of the Fossil Diatomaceous Flora of South Africa.—I. Fossil Diatoms from Diatomaceous Limestones from Pan near Franzenkop and Prieska, Cape Province, S.A." by B. V. SKVORTZOV (communicated by S. H. HAUGHTON).

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 21, 1937, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Meeting of March 17, 1937, were confirmed.

The following were duly elected to Membership of the Society:— LESTER C. KING, J. N. NEETHLING, H. SANDON, J. F. SCHOFIELD.

Communications:—

1. "Archaeology of the Oakhurst Shelter, George."
   (1) "Course of the Excavation," by A. J. H. GOODWIN.
   (2) "Disposition of Skeletal Material," by A. J. H. GOODWIN.
   (3) "The Cave-Dwellers," by M. R. DRENNAN.
   (4) "Children of the Cave-Dwellers," by M. R. DRENNAN.
   (5) "The Pottery," by J. F. SCHOFIELD.

2. "An Unusual Grooved Stone," by P. W. LAIDLER.
3. "Pottery from the Umgazana and Zigzag Caves," by J. F. SCHOFIELD.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 19, 1937, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of April 21, 1937, were confirmed.

The following were nominated for Membership of the Society:—R. W. JAMES and B. N. GOODLET. Both proposed by E. NEWBERY and seconded by A. BROWN.

The President made the following announcements:—Vice-Presidents for 1937 would be J. JACKSON and R. B. YOUNG.

A congratulatory message had been sent to Their Majesties the King and Queen, through the Governor-General, from the Society. A reply had been received stating that the message was being forwarded to Their Majesties.

Communications:—

1. "The South African Inter-Tidal Zone and its Relation to Ocean Currents.—II. "An Area on the Southern Part of the West Coast," by K. F. M. BRIGHT. III. "An Area on the Northern Part of the West Coast," by K. F. M. BRIGHT.
2. "The Odoriferous Glands of South African Harvest Spiders," by R. F. LAWRENCE.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 16, 1937, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of May 19, 1937, were confirmed.

The following were elected to Membership of the Society:—R. W. JAMES, B. N. GOODLET.

The following were nominated for Election to Membership:—

G. BROEKHUYSEN, proposed by R. S. ADAMSON, seconded by W. E. ISAAC; D. BURNETT, proposed by J. L. B. SMITH, seconded by A. BROWN; W. TALBOT, proposed by L. CRAWFORD, seconded by A. BROWN; Mrs. W. TALBOT, proposed by E. NEWBERY, seconded by A. J. H. GOODWIN.

The President announced that Professor W. A. JOLLY had been asked by Council to continue as a Trustee of the South African Museum for a further period of three years.

Communications:—

1. "The South African Fishes of the Families Sparidae and Denticidae," by J. L. B. SMITH.

2. "Archaeology of the Oakhurst Shelter, George.—(6) The Wilton Deposit," by A. J. H. GOODWIN.

DISCUSSION.—"On the Tribes and Languages Represented among the Bushmen Recently brought to Cape Town," introduced by D. F. BLEEK and M. R. DRENNAN.

The discussion was further continued by C. S. GROBBELAAR and G. P. LESTRADE. In conclusion M. R. DRENNAN moved that the Council consider the advisability of submitting to the Government a considered statement on the desirability of a Bushman reserve.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, July 21, 3197, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. J. JACKSON, was in the Chair.

Business:—

The Minutes of the Meeting held on June 16, 1937, were confirmed.

The Vice-President announced the following nominations for Election to Fellowship of the Society:—ANTONIE PETRUS GEHARDUS GOOSSENS, proposed by E. P. PHILLIPS, JOHN PHILLIPS, J. W. BEWS, and N. J. G. SMITH; LEN VERWOERD, proposed by P. A. VAN DER BYL, B. DE ST. J. VAN DER RIET, J. T. MORRISON, A. V. DUTHIE, and C. W. MALLY.

The following were elected Members of the Society:—G. BROEKHUYSEN, D. BURNETT, W. TALBOT, Mrs. TALBOT.

The following were nominated to Membership of the Society:—Miss L. L. BRITTEN, proposed by J. L. B. SMITH, seconded by A. J. H. GOODWIN; J. OMER-COOPER, proposed by J. L. B. SMITH, seconded by A. J. H. GOODWIN; S. W. WATSON, proposed by J. L. B. SMITH, seconded by A. BROWN.

The Vice-President announced that a Coronation Medal had been awarded to Professor L. CRAWFORD, President of the Society.

Communications:—

1. "Archaeology of the Oakhurst Shelter, George.—(6) Stratified Deposits and Contents; (7) Summary and Conclusions," by A. J. H. Goodwin.

2. "Gonadotropic Activity of Amphibian Pituitary," by H. Zwarenstein.

Implantation of 8 to 20 mg. of anterior pituitary tissue of *Xenopus laevis* in immature female mice caused opening of the vagina, enlargement of the ovaries with occasional haemorrhagic follicles (blood spots) and a two to fourfold increase in uterine weight. Control implants of frog's brain, muscle, liver, kidney, spleen and ovary gave negative results.

3. "Notes on the Stranding of a School of Pseudorca Crassidens at Berg River Mouth in December, 1936," by Reay H. Smithers.

4. "Gallium. Part IV. The Phosphates and Arsenates of Gallium," by F. Sebba and W. Pugh.

Gallium ortho-phosphate has been prepared by neutralising a solution of a gallium salt in presence of a phosphate. The gallium is completely precipitated as a gelatinous phosphate. A crystalline variety has been prepared under pressure. Both forms are anhydrous.

The estimation of gallium in these substances and in pure gallium solutions by means of cupferron has been shown to be unreliable.

Gallium ortho-arsenate has been prepared in a similar way and both gelatinous and crystalline forms have been obtained. The arsenate separates as the di-hydrate.

A crystalline complex galli-arsenate has been prepared by using a large excess of arsenate in strongly alkaline solution under pressure.

The precipitation of gallium in presence of arsenates has been shown to be incomplete in neutral solution. The gallium arsenate is peptised. The conditions for complete separation have been investigated and good results are obtainable by precipitation at pH 3.

M. R. Levyns,
Acting Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 18, 1937, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Minutes of the Meeting of July 21, 1937, were confirmed.

The following were elected Members of the Society:—Miss L. Britten, J. Omer-Cooper, S. W. Watson.

The following nomination to Membership of the Society was made:—
D. J. du Plessis, proposed by J. L. B. Smith, seconded by M. R. Levyns.

The President announced that a letter of thanks had been received, acknowledging the message of loyal assurance sent to the King and Queen on the occasion of Their Majesties' Coronation.

Communications:—

1. "Mercurous Perchlorate as a Volumetric Reagent for Chlorides and Bromides," by W. Pugh.

Mercurous Perchlorate is a very convenient reagent for estimating chlorides and bromides. With brom-phenol blue as absorption indicator it gives an excellent colour change at the equivalent point. The results are accurate. It has the advantage over silver nitrate that it can be used in acid solutions. The reagent has been tested on various pure products and on several types of water and the results compare very favourably with those obtained by gravimetric analysis.

2. "Pipes and Smoking in South Africa: an Account of the Typology and Distribution of Pipes of Clay, Stone, and Bone in South Africa," by P. W. Laidler.

3. "The Geographical Distribution of Plants in the Western Portion of the Little Karroo," by M. R. Levyns.

The western portion of the Little Karroo, which is bounded on the North by the Zwartberg and on the South by the Langeberg, has an altitude a little under 2000 feet. Numerous kopjes are dotted over the area. The flora consists largely of succulent plants and the vegetation as a whole is of a very open type. In the part under discussion four mountain ranges with altitudes in the neighbourhood of 5000 feet occur as islands in the Karroo. Towards the summits of these isolated mountains the Cape flora gradually replaces the Karroo flora. This change may be correlated with an increase in rainfall. Many of the plants constituting the mountain-top vegetation have a wide distribution, but some are endemic to one or two of these mountains. Several undescribed species characterise these "island" floras. Many of the kopjes along the northern boundary of the Little Karroo give interesting information with regard to the inter-relations of the Karroo and Cape floras.

4. "The Teeth of South African Fossil Pigs (*Notochoerus capensis syn. Meadowsi*) and their Geological Significance," by J. C. Middleton-Shaw (communicated by Professor Raymond A. Dart).

5. "An Interesting Post-Larval Stage of the 'Galjoen,'" by J. L. B. Smith.

M. R. Levyns,
Acting Hon. General Secretary.

The Annual Meeting of the Society was held on Wednesday, September 15, 1937, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

Election of Fellows. The following were elected:—ANTONIE PETRUS GERHARDUS GOOSSENS, LEN VERWOERD.

ORDINARY MEETING.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Meeting held on August 18, 1937, were confirmed.

L. VERWOERD was admitted to Fellowship of the Society.

D. J. DU PLESSIS was elected to Membership of the Society.

The following were nominated to Membership of the Society:—H. J. KOCH, proposed by J. L. B. SMITH and seconded by A. BROWN; A. BUCHANAN, proposed by E. NEWBERY and seconded by R. H. SMITHERS.

Communication:—

"A Study of the South African Species of *Sporobolus* R. Br., with Special Reference to Leaf Anatomy," by A. P. GOOSSENS.

DEMONSTRATION.—"Stages in the Life-Cycle of Some South African Kelps," by G. F. PAPENFUSS (communicated by M. R. LEVYNS).

M. R. LEVYNS,
Acting Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, October 20, 1937, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Meeting of September 15, 1937, were confirmed.

The President moved that a letter of condolence be sent to the relatives of the late C. F. SILBERBAUER, whose Membership dated from the days of the Philosophical Society of South Africa.

Regret was expressed at the serious illness of Dr. A. W. ROGERS, F.R.S., and the President undertook to convey to him the best wishes of the Society for a speedy recovery.

The Society recorded its deep regret at the death of LORD RUTHERFORD. The Secretary was instructed to send a letter of condolence to Lady Rutherford.

The President announced that the following were recommended by the Council for the incoming Council of 1938:—President, L. Crawford; Hon. Secretary, A. J. H. Goodwin; Hon. Treasurer, A. Brown; Hon. Librarian, E. Newbery; Hon. Editor of the Transactions, M. R. Levyns. Members of Council:—J. W. Bews, R. A. Dart, L. Gill, J. Jackson, S. M. Naudé, M. Rindl, B. J. Ryrie, J. L. B. Smith, J. Steph. van der Lingen.

The following were elected to Membership of the Society:—A. Buchanan, H. J. Koch.

Communications:—

1. "Evolution of a Growth Inhibiting Emanation from Ripening Peaches and Plums," by W. E. Isaac.

2. "A New Gobioid Fish from South Africa," by J. L. B. Smith.

3. "A Note on the Distribution of Chemical Compounds in the Inner and Outer Portions of the Flesh of the Kelsey Plum," by I. Donen.

4. "Complex Fluorides of Gallium and some Heavy Metals," by W. Pugh.

5. "The Development of Teeth in the Radula of Freshwater Mollusca," by F. G. Cawston.

There is a rapid increase in the number of teeth of freshwater mollusca as soon as the radula is put to use after the animal hatches out.

Tricuspid teeth in each row are added to from the marginals, whose cusps coalesce as the animal grows.

Freshwater species possess broad rows of teeth but not so many as some lagoon and land species. The stoutest teeth are those which are exposed to most use. Some increase in size of individual teeth may be expected during the first few months of the animal's existence.

The best illustrations of typical teeth of the various freshwater molluscs are obtained by preparing camera lucida models.

6. "South African Larval Trematodes with Forked Tails whose Life-Cycle is at Present Unknown," by F. G. Cawston.

It is considered important to discover the life-cycle of furcocercous Cercariae if the various forms are to be recognised. Difficulty is experienced in the differential staining of Cercariae. Notes are given on some South African Cercariae.

7. "Descriptions of New Forms of the Genus *Acontias* Lin," by John Hewitt.

Five new subspecies are described, preceded by an introductory account dealing with the forms occurring in Africa and their distribution.

8. "Sulphur as a Factor in the Corrosion of Iron and Steel Structures in the Sea. Part II. Sulphides in Bottom Muds of Certain Harbours of the World," by W. J. Copenhagen (with a Note in the text by Dr. A. W. Rogers, F.R.S.).

In a previous paper reference was made to the occurrence of ferrous sulphide in the corrosion product on the surface of iron and steel vessels and structures when immersed for a period in sea-water.

Bottom muds from two English ports (eight examples); and one sample from each of the following ports: six continental ports; nine African ports; two Australian ports; two American ports, and twenty others including Indian, Malayan, Chinese, Japanese, Dutch East Indian, South Seas, and Panama ports. These were examined for sulphur in the form of ferrous sulphides.

In all cases except open roadsteads, ferrous sulphide was present in the bottom muds in comparatively higher concentration than that of marine muds on the floor of the ocean. The highest concentration was found in a sample from the Port of London, where the ferrous sulphide content was 6·3 per cent.

The origin of the ferrous sulphide in bottom muds has been investigated and is of bacterial origin, *i.e.* (*a*) from decomposition products of waste in harbours, and (*b*) by the reduction of sulphates in sea-water.

Ferrous sulphide under certain conditions is oxidised to ferric oxide and elementary sulphur. The latter rapidly combines with exposed iron (in iron and steel structures) and rapid corrosion of the structures ensues.

Experimental work on the oxygen absorption rate of some of the muds and its biological significance is discussed.

A. W. Rogers has kindly identified the principal minerals in the samples, and a note on this is included.

M. R. Levyns,
Acting Hon. General Secretary.

Report of the Hon. General Secretary for 1937.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the undermentioned papers were read:—

1. "Some Characteristics of *Bulinus* and *Physopsis*," by F. G. Cawston.
2. "Studies of South African Seaweed Vegetation. I. West Coast from Lambert's Bay to Cape Point," by W. E. Isaac.
3. "The Climate and Stone Implements of Rooikop," by J. C. Smuts (communicated by C. van Riet Lowe).
4. "Past Climates and Pre-Stellenbosch Stone Implements of Rietvlei (Pretoria) and Benoni," by J. C. Smuts (communicated by C. van Riet Lowe).
5. "Contributions to our Knowledge of Freshwater Algae of Africa. 12. Algae from the Belfast Pan, Transvaal," by F. E. Fritsch and F. Rich (communicated by E. L. Stephens).

6. "The Florisbad Skull and Brain-Cast," by M. R. Drennan.

7. "Contribution to our Knowledge of the Fossil Diatomaceous Flora of South Africa. I. Fossil Diatoms from Diatomaceous Limestones from Pan near Franzenkop and Prieska, Cape Province, S.A.," by B. V. Skvortzov (communicated by A. W. Rogers).

8. "Archaeology of the Oakhurst Shelter, George."—(1) "Course of the Excavation," by A. J. H. Goodwin. (2) "Disposition of Skeletal Material," by A. J. H. Goodwin. (3) "The Cave-Dwellers," by M. R. Drennan. (4) "The Children of the Cave-Dwellers," by M. R. Drennan. (5) "The Pottery," by J. F. Schofield.

9. "An Unusual Grooved Stone," by P. W. Laidler.

10. "Pottery from the Umgazana and Zigzag Caves," by J. F. Schofield.

11. "The South African Inter-Tidal Zone and its Relation to Ocean Currents."—II. "An Area on the Southern Part of the West Coast," by K. F. M. Bright. III. "An Area on the Northern Part of the West Coast," by K. F. M. Bright.

12. "The Odoriferous Glands of South African Harvest Spiders," by R. F. Lawrence.

13. "The South African Fishes of the Families *Sparidae* and *Denticidae*," by J. L. B. Smith.

14. "Archaeology of the Oakhurst Shelter, George.—(6) Stratified Deposits and Contents," by A. J. H. Goodwin. (7) "Summary and Conclusions," by A. J. H. Goodwin.

15. "Gonadotropic Activity of Amphibian Pituitary," by H. Zwarenstein.

16. "Notes on the Stranding of a School of *Pseudorca crassidens* at Berg River Mouth in December, 1936," by Reay H. Smithers.

17. "Gallium. Part IV. The Phosphates and Arsenates of Gallium," by F. Sebba and W. Pugh.

18. "Mercurous Perchlorate as a Volumetric Reagent for Chlorides and Bromides," by W. Pugh.

19. "Pipes and Smoking in South Africa: an Account of the Typology and Distribution of Pipes of Clay, Stone, and Bone in South Africa," by P. W. Laidler.

20. "The Geographical Distribution of Plants in the Western Portion of the Little Karroo," by M. R. Levyns.

21. "The Teeth of South African Fossil Pigs (*Notochoerus capensis syn. Meadowsi*) and their Geological Significance," by J. C. Middleton-Shaw (communicated by Professor Raymond A. Dart).

22. "An Interesting Post-Larval Stage of the 'Galjoen,'" by J. L. B. Smith.

23. "A Study of the South African Species of *Sporobolus*, R. Br., with Special Reference to Leaf Anatomy," by A. P. GOOSSENS.

24. "Evolution of a Growth-inhibiting Emanation from Ripening Peaches and Plums," by W. E. ISAAC.

25. "A New Gobioid Fish from South Africa," by J. L. B. SMITH.

26. "A Note on the Distribution of Chemical Compounds in the Inner and Outer Portions of the Flesh of the Kelsey Plum," by I. DONEN.

27. "Complex Fluorides of Gallium and some Heavy Metals," by W. PUGH.

28. "The Development of Teeth in the Radula of Freshwater Mollusca," by F. G. CAWSTON.

29. "South African Larval Trematodes with Forked Tails whose Life-Cycle is at present unknown," by F. G. CAWSTON.

30. "Descriptions of New Forms of the Genus *Acontias*, Lin.," by JOHN HEWITT.

31. "Sulphur as a Factor in the Corrosion of Iron and Steel Structures in the Sea. Part II. Sulphides in Bottom Muds of certain Harbours of the World," by W. J. COPENHAGEN (with a Note in the Text by Dr. A. W. ROGERS, F.R.S.).

DISCUSSION.—At the Ordinary Meeting of the Society on June 16, a discussion was held "On the Tribes and Languages Represented among the Bushmen recently brought to Cape Town," introduced by D. F. BLEEK and M. R. DRENNAN.

DEMONSTRATION.—At the Ordinary Meeting of the Society on September 15, G. F. PAPENFUSS gave a Demonstration of "Stages in the Life-Cycle of some South African Kelps" (communicated by M. R. LEVYNS).

Vol. XXIV, parts 3 and 4; Vol. XXV, parts 1 to 3, of the Society's Transactions have been issued during the year.

ANTONIE PETRUS GERHARDUS GOOSSENS and LEN VERWOERD were elected Fellows of the Society.

At the end of 1937 the number of Fellows was 79; Members, 126. During the year one Fellow and five Members resigned. Sixteen new Members were elected during the year.

The deaths during the year of Mr. F. EYLES, Professor H. B. FANTHAM, Dr. A. W. ROBERTS, Mr. C. F. SILBERBAUER, and Professor ANDREW YOUNG are recorded with regret. All have been associated with the activities of the Society for long periods.

The thanks of the Council are due to the Union Government for a Grant of £400 for the year 1937–38; the Council's thanks are due, too, to the University of Cape Town for Grants of £30 and £25 in aid of the publication of papers by K. F. M. BRIGHT, and by G. P. LESTRADE and I. SCHAPERA.

The following gifts have been received by the Library during the year:—

From the French Government, A complete set (10 vols.) of Annual Tables of Constants and Numerical Data; from A. H. WALLIS, Esq., 10 back parts of scientific periodicals; from the International Council of Scientific Unions, Reports of Proceedings, Vol. III, 1937; from the Reichsamt für Wetterdienst, Erfahrungsberichte, Neudrucke, Band 1–2; from the Geological Survey, Great Britain, The First Hundred Years of the Geological Survey of Great Britain, by Sir J. S. FLETT; from the Citrus Experimental Station, Mazoe, Annual Report, 1935; from the Deutches Kolonial- und Ubersee-Museum, Bremen, Führer durch die Sammlungen; from the K. Leopoldisch-Carolinisch deutschen Akad. der Naturforscher, Festgabe aus Anlass der 250 Wiederkehr des Tages der Erhebung, Verzeichnis der periodischen Schriften der Biblioteek.

The following exchange has been discontinued:—The Academy of Sciences of the U.S.S.R., Leningrad.

New exchanges have been arranged with the following institutions:—The Zoological Museum, Berlin; Agricultural Research Station, Rehovoth, Palestine; Fan Memorial Institute of Biology, Peiping.

The following back numbers have been obtained during the year as gifts or by exchange:—Jnl. of the Indian Mathematical Society, Vol. 16, Nos. 1–8, 10, 11, 12; Vol. 17, No. 2; Philippine Journal of Science, Vol. 33, No. 4, Vol. 45, No. 4; Boletin del Cuerpo de Ingenieros Minas del Peru, Lima, Nos. 89, 90, 104, 107, 108, 113, 115; Entomologische Berichten, Vol. 6, 125, 134–137.

The Hon. Secretary represented the Society at the 1937 Meeting of the British Association held at Nottingham in September.

A congratulatory message from the Society was sent to Their Majesties the King and Queen on the occasion of their Coronation, through the Governor-General. A letter of thanks was received, acknowledging the message of loyal assurance.

Forms for the nomination to Membership have been published, and will in future be circulated from time to time. The form for nomination to Fellowship has been revised and simplified.

A. J. H. GOODWIN,
Hon. General Secretary.

The Anniversary Meeting of the Society was held on Wednesday, March 16, 1938, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The following were duly elected as Officers and Council for 1938:—President, L. CRAWFORD; Hon. Secretary, A. J. H. GOODWIN; Hon.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR, JANUARY 1 TO DECEMBER 31, 1937.

DR.

	£ s. d.	£ s. d.
Bank Balance, January 1, 1937		23 8 5
Subscriptions:		
Up to 1935	14 0 0	
1936	47 8 6	
1937 (Fellows)	63 0 0	
1937 (Town Members)	64 0 0	
1937 (Country Members)	60 0 0	
1937 (Life)	85 10 0	
Entrance, etc.	16 0 0	
Advance payment	4 0 0	
		350 2 6
Contribution from Life Fund		48 16 9
Commission received on cheques		1 8 6
Sale of publications		35 2 4
Sale of Extra Reprints		21 4 7
Grants:		
Union Government	400 0 0	
University of Cape Town...	25 0 0	
University of Cape Town...	30 0 0	
		455 0 0
Interest:		
Life Fund (Cape of Good Hope Savings Bank)	13 6 7	
General Fund (Cape of Good Hope Savings Bank)	7 0 0	
P.O. Savings Bank	4 18 6	
Standard Bank Savings Bank...	4 1 0	
		29 6 1
Miscellaneous Receipts		2 0 2
Drawn from Standard Bank Savings Bank ...		100 0 0
		£1066 9 4

CR.

	£ s. d.	£ s. d.
Neill:		
Printing (2 parts)	243 18 7	
Postages, etc.	14 17 8	
Extra Reprints	15 8 2	
		274 4 5
Local Printing Account		42 11 6
Binding Account		61 10 0
Clerical Assistance		48 0 0
Postages and Petties		30 10 8
Bank Charges		4 5 10
Rooms, Caretaker, etc.		42 6 0
Insurance		0 15 0
Miscellaneous		6 17 1
Life Fund:		
Paid in	95 19 6	
Interest	13 6 7	
		109 6 1
Savings Account (G.H.S.B.):		
Paid in	400 0 0	
Interest	7 0 0	
		407 0 0
Post Office Savings Account: Interest		4 18 6
Standard Bank Savings Account: Interest ...		4 1 0
Credit with Neill		0 1 0
Bank Balance		30 2 3
		£1066 9 4

ASSETS AND LIABILITIES AT DECEMBER 31, 1937.

Assets.*	£	s.	d.	Liabilities.	£	s.	d.
Current Balance	30	2	3	Life Fund	445	0	5
Life Fund (Cape of Good Hope Savings Bank)	445	0	5	Binding Account unspent	50	3	9
Savings Account (Cape of Good Hope Savings Bank) ...	407	0	0	Neill: 1937 Account (since paid)	287	5	11
P.O. Savings Account	327	19	0	Cost of Vol. XXV, Part 3	134	17	6
Standard Bank Savings Account	175	9	6	Cost of Vol. XXV, Part 4 (Estim.)	135	0	0
Credit with Neill	0	1	0	Excess of Assets over Liabilities	333	4	7
	£1385	12	2		£1385	12	2

* Exclusive of value of Library, Publications of the Society in stock and other properties.

ALEXANDER BROWN, Hon. Treasurer.

We hereby certify that we have examined the above accounts of Revenue and Expenditure and of Assets and Liabilities, and compared them with the books, vouchers and other documents relative thereto, and that in our opinion these accounts set forth a correct description of the affairs of the Society.

March 7, 1938.

A. OGG.
R. W. JAMES.

Treasurer, A. Brown; Hon. Librarian, E. Newbery; Hon. Editor of the Transactions, M. R. Levyns. Members of Council:—J. W. Bews, R. A. Dart, L. Gill, J. Jackson, S. M. Naudé, M. Rindl, B. J. Ryrie, J. L. B. Smith, J. Steph. van der Lingen.

The Annual Report of the Hon. General Secretary for 1938 was read and passed.

The Report of the Hon. Treasurer for 1938 was adopted.

The President referred to the deaths of Mr. F. Eyles, Professor H. B. Fantham, and Dr. A. W. Roberts with regret. The Society expressed its sympathy, and it was agreed that messages of condolence should be sent to the relatives.

The President expressed the thanks of the Society to Mrs. M. R. Levyns and to B. J. Ryrie for their help as Acting Officers of the Association during part of 1937.

Ordinary Meeting.

The Anniversary Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of October 20 were confirmed.

The following were nominated to Membership of the Society:—Miss A. Lyle, proposed by J. L. B. Smith, seconded by D. Burnett; L. A. Hurst, proposed by H. A. Reyburn, seconded by A. Brown.

Communications:—

"Pottery from the Salisbury District, Southern Rhodesia."—1. "The Topography of Echo Farm, Didcot Farm, and the Ruins on Didcot Farm," by Rev. Fr. Stapleton. 2. "The Pottery from Echo Farm, Didcot Farm, and the Ruins on Didcot Farm," by J. F. Schofield. 3. "A Proposed Classification for the Pottery of Southern Rhodesia," by J. F. Schofield. 4. "Notes on Iron Implements from Echo Farm," by J. F. Schofield.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 20, 1938, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Minutes of March 16 were confirmed.

The Society extended its congratulations to Dr. J. Jackson and to

Dr. B. F. J. SCHONLAND on the occasion of their election to Fellowship of the Royal Society of London.

Miss A. LYLE was elected a Member of the Society.

The following were nominated for Membership:—Miss G. J. LEWIS, proposed by R. S. ADAMSON, seconded by Mrs. M. R. LEVYNS; Miss E. J. ST. LEGER, proposed by Miss M. WILMAN, seconded by J. H. POWER; Dr. R. GOETZ, proposed by E. NEWBERY, seconded by R. SMITHERS.

A letter was read from the Research Grant Board stating that applications for Grants in Aid of Research must be submitted before Monday, May 16, 1938. Forms may be obtained from the Secretary.

Obituaries:—

The President read the following obituary notices:—

ALEXANDER WILLIAM ROBERTS was born at Farr in Sutherlandshire, Scotland, on December 4, 1857, and died at Alice, near Lovedale, Cape Province, on January 27, 1938.

Roberts came to South Africa at the age of twenty-five to undertake educational work amongst the natives and as "Roberts of Lovedale" he will be long remembered. For more than fifty years he laboured in the cause of the natives, at first as a teacher but later also as a leader in the political sphere. He became a Senator to represent them and later a Member, and finally Chairman, of the Native Affairs Commission. On several occasions Roberts was a member of commissions appointed to inquire into disputes or riots involving natives. In 1923 he was chairman of a commission on Native Churches, and in 1930 he was a Member of the Native Economic Commission. He carried on his work on behalf of the natives till a year or two ago, when failing health forced him to retire. This period of his life is marked by an outstanding paper on the probable increase of the native population of the Union, probably the first scientific approach made to that subject.

As an astronomer Roberts will be long remembered for his work on variable stars. When President of the Astronomical Society of South Africa in 1928 he described how he came to take up this branch of work: "My own thoughts since early youth had turned to astronomy, and so in 1888, and after considerable correspondence with Gould and Pickering and consultations with Gill, my lifelong friend, I determined to erect a small observatory at Lovedale for the single purpose of observing southern variable stars and other allied phenomena. I spent two years getting my hand in to the work. . . . In 1890 I entered into the work that I carried on, unbrokenly, for thirty years—thirty happy years."

In 1890 comparatively few variable stars were known south of declination $-30°$, the region in which Roberts worked. At first he had only a second-hand theodolite and a pair of field-glasses, but a telescope with a

rotating prism in front of the object-glass, made by Cooke of York to Gill's design, was presented to him by Sir John Usher in 1900. With this and other instruments he made many thousand observations of the brightness of stars and discovered many variable stars. As a result of his observations he contributed many papers to the Royal Astronomical Society, the Philosophical Society of South Africa, etc. He was specially interested in eclipsing variables. There is no doubt of the high quality of his observations, considering the time at which he worked. Unfortunately many of his observations, especially those of long-period variables, are still unreduced. With so much work in hand he found it difficult to get his reductions up to date. His annual reports to the Royal Astronomical Society show that as early as 1897 he proposed discontinuing observations for the sake of his calculations. At the same time he contributed papers on the source of error in the observation of close pairs of stars, on atmospheric extinction, etc. He was well known as a lecturer on astronomical subjects and in 1934, on the occasion of the centenary celebrations in connection with the arrival of Sir John Herschel in South Africa, he lectured to crowded audiences of coloured children in Cape Town.

It is largely due to the influence of Roberts that a band of active amateur observers in astronomy has grown up in South Africa. His astronomical work was recognised by the University of Cape Town, which conferred on him the degree of D.Sc.

Harold Benjamin Fantham (1876–1937), a Fellow of this Society, was an outstanding Zoologist and Parasitologist. He held the degrees of M.A., Cantab. (Christ's College) and D.Sc., London. At London he was the recipient of the Gold Medal for Zoology, and Derby Research Scholar. At Cambridge he was Darwinian Prizeman and University Assistant to the Quick Professor of Biology. He was a Fellow of the University of London.

During the past thirty-three years Dr. Fantham has been actively engaged as a University teacher and in research. He has held posts in the St. Mary's Hospital Medical School and University College, London, and in the Liverpool School of Tropical Medicine. In 1917 Dr. Fantham was appointed as the first Professor of Zoology and Comparative Anatomy in the University of the Witwatersrand. He developed the school both as a lecturing and as a research centre. In 1927 he was elected President of the South African Association for the Advancement of Science, at their Salisbury meeting. In 1931 he received the South African Medal and Grant. At that time his recorded bibliography contained over one hundred and thirty papers, many of which were written in collaboration with his wife, Dr. Annie Porter. He was elected a Fellow of this Society and twice acted as Vice-President.

In 1933 Dr. Fantham became Strathcona Professor of Zoology at

McGill University, Montreal, and developed the department as a centre for zoological ecology. During his period of office in Canada he was the official representative of this Society at various scientific congresses both in that Dominion and in the United States.

Apart from his outstanding work on human heredity, on animal parasitology, zoological ecology and eugenics, Dr. FANTHAM showed marked artistic gifts as a musician and an artist, and was an inspiring and convincing speaker. He died of septicaemia on October 26, 1937, and is to be buried in Cambridge. In his death science loses an active leader in zoology, education and eugenics, and a research worker of outstanding merit.

Professor ANDREW YOUNG, M.A., D.Sc., was born in 1873 near Perth, Scotland, and died in Cape Town on November 7, 1937. He studied at Edinburgh University, where he distinguished himself in Geology and Mineralogy, his teachers in these subjects being the late Professor James Geikie and Dr. (now Sir) John Flett. He also attended the Normal Training College in the same city and for several years afterwards was engaged in educational work, including the organisation of science teaching in Gloucestershire and lecturing on Geology at the Heriot-Watt College, Edinburgh. In 1902 he was appointed to the Chair of Geology at the South African College (afterwards the University of Cape Town) vacated by the late Dr. G. S. Corstorphine, its first occupant.

As a geologist Professor YOUNG interested himself particularly in the underground water conditions of Cape Colony, and was the first to observe and study tidal phenomena in the deep-seated subterranean waters of that region. A paper written by him on this subject was read before the Royal Society of South Africa in 1913, and appears in Vol. 3 of its Transactions. His interests and intimate knowledge, however, embraced a very wide field, and he would be more aptly described as a scholar than as a specialist. As a teacher he succeeded in arousing enthusiasm in his students, several of whom adopted geology as their life-work and have since attained distinction in the science. Professor YOUNG was a man of genial temperament and generous disposition and made many friends.

The death of FRED EYLES has removed a Member of long standing and the foremost pioneer botanist of Southern Rhodesia. Eyles was probably better acquainted with the flora of that country than any other person. Knowledge of the flora, indeed, rests to a large extent on his discoveries and collections. His name is perpetuated in many species of which he was the discoverer.

EYLES's published contributions to science are not numerous: probably the most important is his account of the flora of Southern Rhodesia that was published by the Society in 1916.

For several years EYLES was Botanist to the Department of Agriculture

of Southern Rhodesia. It was during his tenure of this post that he carried out most of his collecting work and amassed a large herbarium. On his retiral from the Government service he became Curator of the Victoria Museum in Salisbury, a post that he held to the time of his death. EYLES was a Fellow of the Linnean Society of London.

Mr. C. F. SILBERBAUER was a Foundation Member of the South African Philosophical Society, and in its early days attended its meetings. Later, when the Philosophical Society was merged into the Royal Society of South Africa he continued his membership until his death, and though for many years resident in Switzerland, he always retained his interest in the Society.

Communications:—

"Therapeutics, Past and Present," by J. W. C. GUNN.

"The Effect of Alcohol and Alcoholic Extracts on Growth of Tissues *in vitro*," by W. S. S. LADELL.

"A Preliminary Study of the Prehistoric Beads of the Northern Transvaal and Natal," by J. F. SCHOFIELD.

"Some Transvaal Desmids," by F. RICH (communicated by Miss E. L. STEPHENS).

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 18, 1938, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of April 20, 1938, were confirmed.

The President nominated E. L. GILL and R. A. DART as Vice-Presidents for 1938.

Miss G. J. LEWIS and Dr. R. GOETZ were elected to Membership.

Communications:—

"*Lecithostaphylus canthari*, n.sp., a Trematode Parasite of the Hottentot Fish *Spondyliosoma blochii*, found in South African Waters," by the late H. B. FANTHAM (communicated by C. VON BONDE).

"A Sociological Sketch of Southern Sotho Diet," by E. H. ASHTON (communicated by I. SCHAPERA).

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 15, 1938, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of April 20, 1938, were confirmed.

Communications:—

"Succession of Teeth in Molluscs," by F. GORDON CAWSTON.

A comparison is made of the relative length of the radulae of terrestrial and freshwater molluscs, the former possessing many posterior rows of teeth which can never come into play.

Terrestrial species being more exposed to injury during feeding show more sign of constant succession of teeth than do the shorter radulae of freshwater species, which also contain far more teeth in each row.

The radulae of fourteen distinct species are here described with special reference to their dimensions, number of teeth in each row, total number of teeth, blunted anterior rows, and embryonic posteriad rows.

A comparison of embryonic radulae with those of the adult shows that some increase in size of the teeth occurs in both terrestrial and freshwater molluscs.

"The Work of R. Research Ship *Discovery II*," by H. F. P. HERDMAN, of the *Discovery*.

"Plant Life in the Southern Ocean," by T. J. HART, of the *Discovery*.

"The Quartz Horizontal Intensity Magnetometer (Q.H.M.)," by A. OGG, B. GOTSMAN, and K. W. SIMPSON.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, July 20, 1938, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The Vice-President, Dr. E. L. GILL, was in the Chair.

Business:—

The Minutes of June 15, 1938, were confirmed.

The Vice-President announced the following nominations for Election to Fellowship of the Society:—LOUIS P. BOSMAN, proposed by W. A. JOLLY, C. VON BONDE, J. SMEATH THOMAS, H. ZWARENSTEIN; DAVID BURNETT, proposed by A. OGG, J. SMEATH THOMAS, R. S. ADAMSON, N. J. G. SMITH; C. J. VAN DER HORST, proposed by T. A. STEPHENSON, D. M. WATT, R. F.

LAWRENCE, JOHN PHILLIPS; REGINALD WILLIAM JAMES, proposed by A. OGG, H. H. PAINE, R. S. ADAMSON, B. J. SCHONLAND; SYDNEY HAROLD SKAIFE, proposed by C. VON BONDE, T. A. STEPHENSON, R. F. LAWRENCE, J. W. BEWS.

Miss E. S. MOORE was nominated to Membership of the Society, proposed by E. L. STEPHENS, seconded by R. S. ADAMSON.

It was proposed by Professor NEWBERY and seconded by Dr. R. GOETZ that Dr. GILL should communicate with the Director of Fisheries with a view to obtaining for scientific purposes some of the seals which are being killed in False Bay.

Communications:—

"Studies in South African Ricciaceae.—II. The Annual Species of the Section Ricciella (concluded); *R. compacta* sp. nov., and *R. Rautanenii* Steph.," by A. V. DUTHIE and S. GARSIDE.

"Some Evidence Bearing on the Past History of the Cape Flora," by M. R. LEVYNS.

M. R. LEVYNS,
Acting Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 17, 1938, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of July 20, 1938, were amended to read: "The Vice-President announced that the following were recommended by Council for election to Fellowship of the Society."

The amended Minutes were confirmed.

Nominations to Membership:—H. A. SHAPIRO, proposed by W. A. JOLLY, seconded by H. ZWARENSTEIN; L. F. MAINGARD, proposed by R. A. DART, seconded by M. R. DRENNAN.

Communications:—

"The Morphology and Classification of Ground and Polished Stone Artefacts of South African Origin," by P. W. LAIDLER.

"Growth Changes and Variations in Wart-hog Third Molars and their Palaeontological Importance," by J. C. MIDDLETON-SHAW (communicated by M. R. DRENNAN).

"Seasonal Variations in Sensitivity to Progesterone-induced Ovulation," by H. ZWARENSTEIN.

"The Biological Standardisation of certain Steroids: (1) Seasonal Changes

in Response of *Xenopus laevis* to Methyl Testosterone." by H. A. SHAPIRO (communicated by H. ZWARENSTEIN).

Methyl testosterone can induce ovulation in *Xenopus laevis.* The ovulation response of the animals to different doses of this steroid was investigated in July 1937, and in January, April, and August 1938. At least forty animals were injected for each dose level. The dose in γ was plotted against the response per cent.

In the characteristic curves obtained the steepness of the curves was very much more marked in those experiments which were done during the breeding season, viz. July and August, than in those done in between the breeding seasons, viz. January and April. The dose required to produce ovulation in 50 per cent. of the animals (referred to as OD50) was approximately elevenfold greater in April than it was in August, when it was 33·0 γ. The smallest dose capable of producing a response was also elevenfold greater in April than in August, when it was 5·0 γ. The logarithm of the dose in γ when plotted against the response per cent. gave a straight line in all four experiments.

A. J. H. GOODWIN,
Hon. General Secretary.

The Annual Meeting of the Society was held on Wednesday, September 21, 1938, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The following were duly elected Fellows of the Society:—L. P. BOSMAN, B.A., B.Sc., Ph.D., Ch.B.; D. BURNETT, M.A., B.Sc., Ph.D.; R. W. JAMES, M.A., B.Sc., F.Inst.P.; S. H. SKAIFE, M.A., M.Sc., Ph.D., F.E.S.; C. J. VAN DER HORST, D.Sc.

ORDINARY MEETING.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of August 17, 1938, were confirmed.

The following were elected to Membership:—L. F. MAINGARD, Miss E. S. MOORE, H. A. SHAPIRO.

H. R. RAIKES, proposed by J. P. DALTON, and seconded by H. H. PAINE, was nominated to Membership.

The President announced that under the powers given to Council by Chapter III, 8 of the Statutes of the Society, Principal H. R. RAIKES, of the

Witwatersrand University, is nominated for Ordinary Fellowship of the Society. Council is of opinion that the Candidate has rendered conspicuous service to the cause of Science in South Africa, and further, that his Election would be of signal service and benefit to the Society. Proposed by L. CRAWFORD, A. BROWN, Mrs. M. R. LEVYNS, E. NEWBERY, and A. J. H. GOODWIN. Letters confirming the proposal were received from various outside Members of Council.

The Nomination was accepted for Election, which will take place on October 19, 1938.

Communications:—

"A *coup-de-poing* Factory Site in the Nieuwveld," by W. G. SHARPLES.

"Population Fluctuation over 7000 Years in Egypt," by RAYMOND A. DART.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, October 19, 1938, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of September 21, 1938, were confirmed.

H. R. RAIKES was elected a Fellow of the Society.

The President announced that Council had proposed the following for Election to Council at the Anniversary Meeting to be held in March 1939:—President, L. CRAWFORD; Secretary, A. J. H. GOODWIN; Treasurer, A. BROWN; Editor, Mrs. M. R. LEVYNS; Librarian, E. NEWBERY. Council Members, J. JACKSON, E. L. GILL, R. A. DART, L. VERWOERD, D. BURNETT, J. W. BEWS, M. RINDL, R. W. JAMES, C. J. VAN DER HORST.

Communications:—

"Skull Thickness and External Measurements in Relation to Capacity," by A. J. H. GOODWIN.

Research detailing the relationship of skull thickness to internal capacity was described. It was pointed out that skull thickness varies from 2·3 mm. average to 8·3 mm., with a difference in the region of three per cent. of capacity for each millimetre of skull thickness. Maximum length, plus width, plus supra-auricular height is employed in relation to skull thickness to determine internal capacity.

"Production of Secondary Rays in Copper by Cosmic Radiation," by P. J. G. DE VOS (communicated by S. M. NAUDÉ).

Cosmic rays produce showers of secondary rays in any matter traversed. The density of this secondary radiation increases with the thickness of material traversed, reaches a maximum, and then decreases again. The form of this curve was found in the case of copper by means of Geiger-Müller counters.

A description is given of the reliable counters constructed, a high voltage source working from the town supply, and a circuit selecting only the coincident discharges of the counter tubes.

The thickness of copper under which a maximum of secondary rays occur can be calculated by means of the theoretical formulae of Bhabha and Heitler. The calculated and experimentally found thicknesses show good agreement.

The absorption of the secondary rays from copper in lead shows the presence of two components of secondary rays having absorption coefficients ·69 and ·30 cm. $^{-1}$Pb respectively.

A. J. H. Goodwin,
Hon. General Secretary.

"A *coup-de-poing* Factory Site in the Nieuwveld," by W. G. Sharples.

A site at Steenkamp's Poort in the Nieuwveld is surprisingly rich in *coups-de-poing*, in dolerite and lydianite. Associated with them are a number of flakes and points. Many of the *coups-de-poing* appear to be made from rough fragments of rock. Some are typically Stellenbosch and some typically Fauresmith in appearance. It is suggested that this is a factory site and that it is an example of Stellenbosch developing into Fauresmith. [Read September 21, 1938.]

Report of the Hon. General Secretary for 1938.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the undermentioned papers were read:—

1. "The Topography of Echo Farm, Didcot Farm, and the Ruins on Didcot Farm," by Rev. Fr. Stapleton.
2. "The Pottery from Echo Farm, Didcot Farm, and the Ruins on Didcot Farm," by J. F. Schofield.
3. "A Proposed Classification for the Pottery of Southern Rhodesia," by J. F. Schofield.
4. "Notes on Iron Implements from Echo Farm," by J. F. Schofield.
5. "Therapeutics, Past and Present," by J. W. C. Gunn.
6. "The Effect of Alcohol and Alcoholic Extracts on Growth of Tissues *in vitro*," by W. S. S. Ladell.

7. "A Preliminary Study of the Prehistoric Beads of the Northern Transvaal and Natal," by J. F. SCHOFIELD.

8. "Some Transvaal Desmids," by F. RICH (communicated by Miss E. L. STEPHENS).

9. "*Lecithostaphylus canthari*, n. sp., a Trematode parasite of the Hottentot fish *Spondyliosoma blochii*, found in South African Waters," by the late H. B. FANTHAM (communicated by C. VON BONDE).

10. "A Sociological Sketch of Southern Sotho Diet," by E. H. ASHTON (communicated by I. SCHAPERA).

11. "Succession of Teeth in Molluscs," by F. GORDON CAWSTON.

12. "The Work of R. Research Ship *Discovery II*," by H. F. P. HERDMAN, of the *Discovery*.

13. "Plant Life in the Southern Ocean," by T. J. HART, of the *Discovery*.

14. "The Quartz Horizontal Intensity Magnetometer (Q.H.M.)," by A. OGG, B. GOTSMAN, and K. W. SIMPSON.

15. "Studies in South African Ricciaceae.—II. The Annual Species of the Section Ricciella (concluded); *R. compacta* sp. nov., and *R. Rautanenii* Steph.," by A. V. DUTHIE and S. GARSIDE.

16. "Some Evidence Bearing on the Past History of the Cape Flora," by M. R. LEVYNS.

17. "The Morphology and Classification of Ground and Polished Stone Artefacts of South African Origin," by P. W. LAIDLER.

18. "Growth Changes and Variations in Wart-hog Third Molars and their Palaeontological Importance," by J. C. MIDDLETON-SHAW (communicated by M. R. DRENNAN).

19. "Seasonal Variations in Sensitivity to Progesterone-induced Ovulation," by H. ZWARENSTEIN.

20. "The Biological Standardisation of Certain Steroids.—(1) Seasonal Changes in Response of *Xenopus Laevis* to Methyl Tetosterone," by H. A. SHAPIRO (communicated by H. ZWARENSTEIN).

21. "A *coup-de-poing* Factory Site in the Nieuwveld," by W. G. SHARPLES.

22. "Population Fluctuation over 7000 Years in Egypt," by RAYMOND A. DART.

23. "Skull Thickness and External Measurements in Relation to Capacity," by A. J. H. GOODWIN.

24. "Production of Secondary Rays in Copper by Cosmic Radiation," by P. J. G. DE VOS (communicated by S. M. NAUDÉ).

Volume XXV, part 4, and Vol. XXVI, parts 1–4 of the Society's Transactions have been issued during the year.

LOUIS P. BOSMAN, DAVID BURNETT, C. J. VAN DER HORST, REGINALD WILLIAM JAMES, and SYDNEY HAROLD SKAIFE were elected Fellows of

the Society in 1938. HUMPHREY RIVAZ RAIKES was elected an Ordinary Fellow under the powers given to Council in the Statutes, Chap. III, Section 8.

At the end of 1938 the number of Fellows was 83, Members 122. During the year two Members resigned, six new Members were elected, and one former Member rejoined the Society.

The deaths during the year of Dr. J. W. BEWS, Dr. F. V. ENGELENBURG, Dr. J. PETERSON, and Dr. T. R. SIM are recorded with regret.

The thanks of the Council are due to the Union Government for a Grant of £400 for the year 1938–39. The Council's thanks are due, too, to the University of Cape Town for a Grant of £30 in aid of publishing a paper by K. F. M. BRIGHT, and to the National Research Council and Board for a Grant in aid of publishing a paper by F. G. FRITSCH and F. RICH.

The following gifts have been received by the Library during the year:—

From F. R. BEAUDETTE, N.Y. Agricultural Experim. Station, New Brunswick, U.S.A., 22 reprints by the donor; from the Canadian Government, Reports of the Canadian Arctic Expedition, 1913–1918; from H. F. P. HERDMAN of the R.R.S. *Discovery*, Report on the Progress of the *Discovery* Committee's Investigation (June 1937); from the Kaffrarian Museum, Annual Report for 1937; from the Mazoe Citrus Experimental Station, Report for 1936; from Miss M. WILMAN, The Bantu Tribes of South Africa, by A. M. DUGGAN-CRONIN, Vol. III, Section III; from A. H. WALLIS, Through Two Solar Cycles: Memorandum to accompany Graph 1917–1918.

New exchanges have been arranged with the following institutions:— Museo Civico di Storia Naturale, Milan; Zoological Museum, Warsaw; University of Missouri, Columbia, U.S.A.; U.S. Dept. of Agriculture, Washington, D.C., U.S.A.; Instituto Botanico, Universidade de Coimbra, Portugal; Geographische Gesellschaft, Hamburg; Botanisch Museum en Herbarium, Rijks Universiteit te Utrecht; Marine Biological Laboratory, Plymouth.

The following exchange has been reinstated:—Academy of Sciences of the U.S.S.R.

In addition to the other publications of the University of California, the Library is now receiving their Publications in Geography and Publications in Pharmacology.

The Society is indebted to H. F. P. HERDMAN and T. J. HART, of the R.R.S. *Discovery*, for papers read at the June Meeting.

The thanks of the Society are due to the Librarian and staff of the University Library for checking the R.S. Library Catalogue with the shelves and typing some 500 cards for inclusion in the new edition of Lloyd's List of Scientific Serials, which is being prepared.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR JANUARY 1 TO DECEMBER 31, 1938.

DR.

	£	s.	d.	£	s.	d.
Bank Balance at January 1, 1938				30	2	3
Subscriptions:						
Up to 1936	4	0	0			
1937	16	0	0			
1938 (Fellows)	38	0	0			
1938 (Town Members)	55	16	0			
1938 (Country Members)	63	0	0			
1938 (Life Members)	221	10	0			
1938 (Entrance Fees, etc.)	7	1	6			
				405	7	6
Contribution from Life Fund				56	18	7
Commission received on cheques				1	6	6
Sale of publications				37	4	6
Sale of reprints				74	17	9
Grants:						
Union Government	400	0	0			
Carnegie Fund	30	0	0			
University of Cape Town...	30	0	0			
				460	0	0
Drawn from Savings Accounts:						
P.O. Savings Bank	270	0	0			
Standard Bank	170	0	0			
Good Hope Savings Bank	300	0	0			
				740	0	0
Interest:						
P.O. Savings Bank	7	13	6			
Standard Bank Savings Bank	1	15	7			
Good Hope Savings Bank (General Fund)	12	9	10			
Good Hope Savings Bank (Life Fund) ...	14	10	3			
Rand Provident Building Society	8	0	0			
				44	9	2
Miscellaneous Receipts				3	17	11
				£1854	4	2

CR.

	£	s.	d.	£	s.	d.
Neill:						
Printing (7 Parts)	943	9	8			
Postages	52	13	8			
Reprints	59	19	1			
				1056	2	5
Local Printing				34	2	6
Binding				108	18	6
Clerical Assistance				49	6	0
Postages and Petty Cash				18	0	0
Bank Charges				4	5	2
Rent, Caretaker, etc.				6	5	0
Miscellaneous Charges				24	8	9
Insurance				1	5	0
Paid into Life Fund	23	0	0			
Deposit with Rand Provident Society	400	0	0			
				423	0	0
Interest deposited in Accounts:						
P.O. Savings Bank	7	13	6			
Standard Bank	1	15	7			
G.H.S.B. (General Fund)...	12	9	10			
G.H.S.B. (Life Fund)	14	10	3			
				36	9	2
Bank Balance at December 31, 1938				92	1	8
				£1854	4	2

R. W. JAMES.
A. OGG.

ALEXANDER BROWN, Hon. Treasurer.

ASSETS AND LIABILITIES AT DECEMBER 31, 1938.

Assets.*	£	s.	d.	Liabilities.	£	s.	d.
Current Account Balance	92	1	8	Life Fund	593	12	1
P.O. Savings Account	65	12	6	Neill (Vol. XXVI, Part 4) (Estim.)	150	0	0
Standard Bank Savings Account	7	5	1	Rent of Rooms and Insurance	36	15	0
Good Hope Savings Account (General)	119	9	10	Binding (Unpaid) (Estim.)	40	0	0
Good Hope Savings Account (Life)	425	12	1	Excess of Assets over Liabilities	289	14	1
Rand Provident Deposit	400	0	0				
	£1110	1	2		£1110	1	2

* Exclusive of value of Library, Publications of the Society in stock, and other properties.

ALEXANDER BROWN, Hon. Treasurer.

We hereby certify that we have examined the above accounts of Revenue and Expenditure, and compared them with the books, vouchers, and other documents relative thereto, and that in our opinion these accounts set forth a correct description of the affairs of the Society.

R. W. JAMES.
A. OGG.

Eighty periodicals were issued from the Society's Library during the year.

Binding:—

As an experiment, 111 volumes were sent for binding to Chivers, of Bath, England. Apart from the unavoidable delay, it was found to be most satisfactory, cost being lower and the standard of work higher than can be obtained locally.

In addition, 320 volumes were bound by the Rustica Press, making 431 volumes in all.

A. J. H. Goodwin,
Hon. General Secretary.

Anniversary Meeting.

The Anniversary Meeting of the Society was held on Wednesday, March 15, 1939, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Annual Report of the Hon. General Secretary for 1938 was read and passed.

The Annual Report of the Hon. Treasurer for 1938 was read and passed.

The following were elected Officers and Council for 1939:—President, L. Crawford; Hon. Treasurer, A. Brown; Hon. Gen. Secretary, A. J. H. Goodwin; Hon. Editor of the Transactions, Mrs. M. R. Levyns; Hon. Librarian, E. Newbery. Members of Council:—D. Burnett, R. A. Dart, E. L. Gill, J. Jackson, R. W. James, M. Rindl, C. J. van der Horst, L. Verwoerd.

Ordinary Meeting.

The Anniversary Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of October 19, 1938, were confirmed.

The following were nominated to Membership of the Society:—S. F. Bush, proposed by R. F. Lawrence, seconded by A. J. H. Goodwin; J. C. Middleton-Shaw, proposed by R. A. Dart, seconded by A. Galloway; J. M. Latsky, proposed by S. H. Skaife, seconded by A. J. H. Goodwin; Frederick Walker, proposed by A. Brown, seconded by R. S. Adamson; L. C. Young, proposed by A. Brown, seconded by R. W. James.

A. Brown moved the congratulation of the President on the conference of the degree of LL.D. *honoris causa* by the University of the Witwatersrand.

The President congratulated I. Schapera and W. Pugh on attaining the D.Sc. of London University, and J. H. Dobson on having been awarded the Moulton Gold Medal for Research by the Institute of Chemical Engineers.

Communications:—

"A Surviving Fish of the Order Actinistia," by J. L. B. Smith.

"Marine Fishes of Two Families and Two Genera New to South Africa," by J. L. B. Smith.

"A Hitherto Undescribed Industry from Mfongosi, Zululand," by D. D. Niddrie (communicated by J. Schofield).

"Some Observations on the Alleged Succession of Teeth in Snakes," by F. G. Cawston.

Most successional teeth develop at the base of a vacant alveolus and face the same direction as shed teeth.

In snakes continued renewal is suggested only in the *vagina dentis*, in which some of the fangs develop.

The solid teeth of snakes which shed leave empty cavities, these contain no indication of replacing teeth.

Even the spike-like extra teeth of snakes may come into use. Though sometimes as large as teeth in the maxillary and palatine rows, these irregular teeth are supernumerary rather than supplementary.

Only the reserve fangs lie out of use, and some of these are hollow and may function when the foremost are deeply embedded.

They may function even before the foremost fangs are removed. Old snakes have the same number of reserves as young snakes. Further investigations are needed before the theory of constant replacement is accepted.

Succession of teeth would imply that the shed teeth are completely replaced by reserve ones.

"Some Observations on the Arrangement of Teeth in Fishes," by F. G. Cawston.

The hinder teeth of most fishes are directed backwards to retain food, like the simple teeth of *Rhineodon* and brier-like teeth of *Chlamydoselachus*, in contrast to erect chopping foremost teeth.

Many triangular teeth of sharks are fin-like, *e.g.* those of *Carcharhinus* and *Galeocerdo*, the anterior edge of both teeth and fins corresponding, as does the posterior border, in accordance with the strong currents of water in which these fishes feed.

Teeth of the foremost rows are usually distinguishable as belonging to one horizontal row. In *Mugil saliens* Risso and allied fishes the posterior rows are too overcrowded to place in rows.

These reserve teeth do not always move forward to fill an empty space, so that shedding is not always followed by replacement, the occasional turning forward of posterior teeth occurring independently of shedding, especially during feeding.

The majority of teeth in *Carcharhinus* and *Carcharias* are arranged in parallel rows on the ribbon-like gum, but the back teeth of the latter species resemble those of small teleostean fishes in that the teeth are arranged rather diagonally.

Raia and *Dasybatis* also possess teeth in diagonal rows. Those at the tooth border are constantly blunted as though in the act of being shed.

Local disturbance of dental germ in *Batoidei* has given rise to the idea of stunted teeth replacing normal ones in these fishes.

The crowded teeth of *Pagrus* cannot be placed in rows, and a lost tooth results in some approximation of those round the empty cavity.

"A Method of Correcting an Objective Noise-Meter for Use on Composite Tones," by R. GUELKE (communicated by B. L. GOODLET).

"New Fossil Elephant Remains from the Victoria Falls, Northern Rhodesia, and a Preliminary Note on the Geology and Archaeology of the Deposit," by H. B. S. COOKE and J. DESMOND CLARK.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 19, 1939, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of March 15, 1939, were read, and after the following additions had been made, they were passed.

The President announced that following upon a postal vote, certain changes in the dates of meetings would be made. No July meeting will be held in future. The Session will be extended to include a November meeting. The Annual Meeting for the election of Fellows will be held in October.

The President reported that a letter of thanks signed by all the visiting Netherlands Botanists had been received, and would be filed in the Library.

The President stated that the Society had been represented on a deputation to the General Purposes Committee of the City Council, with the intention of making the Herschel Obelisk accessible to the public at all times.

The final paper, by H. B. S. COOKE and J. DESMOND CLARK, was communicated by C. VAN RIET LOWE.

Membership:—

The following were elected to Membership of the Society:—S. F. BUSH, J. C. MIDDLETON-SHAW, J. M. LATSKY, FREDERICK WALKER, and L. C. YOUNG.

Vice-Presidents:—

The President announced that Dr. J. JACKSON and Professor RAYMOND DART had been selected as Vice-Presidents for 1939.

Communications:—

"A Further Contribution to the Knowledge of the Vertical Distribution of certain Intertidal Marine Gastropods in False Bay, South Africa," by G. J. BROEKHUYSEN.

"Three Mites Living on South African Millipedes," by R. F. LAWRENCE.

"Further Note on the Comparison of the Quartz Horizontal Magnetometers Nos. 29 and 30," by K. W. SIMPSON and A. N. VAN WYK (communicated by A. OGG).

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 17, 1939, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Meeting of April 19, 1939, were read and passed.

The President announced that the following letter had been sent to the Minister of Defence:—

April 26, 1939.

DEAR SIR,—There is being prepared in London a register of persons willing to serve in professional capacities in the event of war. Inclusion in this register implies an obligation to serve (in time of war) in an appropriate way in their professional capacity and to accept such suitable work as is offered to them.

The Royal Society of London has been asked to co-operate by compiling the section of the register dealing with persons normally engaged in, or qualified to undertake, scientific research.

Enquiries have been made as to a list in South Africa of workers, such as in the previous paragraph, who are prepared to offer their services here or

overseas in the event of war. The Royal Society of South Africa would gladly offer its services and help in framing such a list.—Yours faithfully,

(Signed) LAWRENCE CRAWFORD, President.

The letter was duly acknowledged on April 29, 1939.

F. W. STRYDOM, proposed by M. R. DRENNAN, and seconded by A. J. H. GOODWIN, was nominated to Membership of the Society.

Communications:—

"The Stellenbosch Industry in the Wagenmakers Valley," By F. MALAN (communicated by A. J. H. GOODWIN).

"Early Pluviation and the Prepalaeolithic Pebble and Flake Artifacts of the Witwatersrand," by J. C. SMUTS, Jun. (communicated by A. J. H. GOODWIN).

"Stone Implements of the Eastern Limpopo Basin," by J. C. SMUTS, Jun. (communicated by A. J. H. GOODWIN).

"A Preliminary Note on the Gill Rakers of Natal Fishes," by F. GORDON CAWSTON.

An attempt is made to determine the various uses of gill-rakers by examining their structure in carefully identified species of marine fish off the Natal Coast.

Gill-rakers guard the entrance to the gill-clefts and prevent prey escaping through the gill-slits. If they served to remove the scales of prey "Scale-rakers" might be a more appropriate term for them.

The numerous spikes which project from gill-rakers indicate a retentive function, whilst a vascular appearance of many suggests constant absorption of nourishment from plants and prey attached to the gill-arches.

No evidence was observed of injury to the rakers during life, and microscopic examination of young examples revealed no replacement such as is seen in the maxillary and palatine rows of teeth.

"A Stone Bead Industry of the Western Transvaal," by H. S. HARGER.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 21, 1939, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of May 17, 1939, were confirmed.

Arising out of the Minutes, the President read a letter from Dr. H. O. MÖNNIG with reference to the letter sent to the Minister of Defence. The

writer put forward the view that a scientist "devotes himself to his work in order to promote the welfare and happiness of mankind. . . . If the results of his work are misused and the science which he has helped to build up is prostituted to serve the purposes of war . . . this can only be a cause for the greatest disappointment and regret to the true scientist. But that he should be called upon, and even offer his services, to assist in this prostitution of science, and to apply his scientific ability for the purpose of promoting man's inhumanity, passes all my understanding."

It was proposed by A. Brown, and seconded by A. Ogg, that the letter from which the above is a short extract be submitted to Council.

F. W. Strydom was elected to Membership of the Society.

Communications:—

"A Living Coelacanthid Fish of Triassic Type from South Africa," by J. L. B. Smith.

"A Projection Method of Mapping from Air Photographs," by H. G. Fourcade.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 16, 1939, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Minutes of the Meeting of June 21, 1939, were confirmed.

The President referred to the deaths of W. A. Jolly, past President and past Secretary of this Society, and of P. A. van der Byl, Fellow. The Meeting confirmed his expressions of sympathy with the relatives of the deceased.

The President, after reading his original letter to the Minister of Defence, and the original letter from Dr. H. O. Mönnig, read the following extract from Council Minutes for July 31, 1939:—

"It was agreed that a letter on the following lines be read at the next Ordinary Meeting, and sent to the writer:

"Council endorses the action of the President in sending the letter of April 26, 1939, to the Minister of Defence. There is no intention expressed in the letter to lay down a policy in regard to war, but in case of any national emergency the Society is prepared to help to make available, for the purposes of the State, the special aptitudes of its Fellows and Members."

It was proposed by A. Ogg that this reply be forwarded to Dr Mönnig. Passed *nem. con.*

The following recommended nominations for Election to Fellowship were read by the President:—William Francis Barker, proposed by W. Pugh, J. Smeath Thomas, D. Burnett, and N. J. G. Smith; Gérard Paul Lestrade, proposed by I. Schapera, T. A. Stephenson, B. J. Ryrie, and R. E. Adamson; Lucien Fernand Maingard, proposed by J. P. Dalton, H. E. Wood, John Phillips, B. J. Schonland, and H. H. Paine; Mary Agard Pocock, proposed by R. S. Adamson, E. L. Stephens, T. A. Stephenson, and N. J. G. Smith; John Vernon Lockhart Rennie, proposed by S. H. Haughton, R. B. Young, A. du Toit, and A. W. Rogers.

Christiaan Lodewyk Wicht was nominated for election to Membership, proposed by J. T. Morrison, seconded by S. M. Naudé.

Communications:—

"The Rôle of Sorbitol in the C-Metabolism of the Kelsey Plum. —I. Changes in Chemical Composition during Growth and Storage," by I. Donen. II. "Relation of Carbohydrate and Acid Loss to CO_2 Production in Stored Plums," by I. Donen and E. R. Roux.

"Electro-magnetic Induction in Water," by H. D. Einhorn (communicated by E. Newbery).

"Orientable Manifolds Constructed from a Solid Cube," by D. B. Sumner (communicated by A. Brown).

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, September 20, 1939, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of August 16, 1939, were passed.

The President drew the attention of the Society to the death of Sir Spencer Lister, Fellow of the Society. The Meeting confirmed his expression of sympathy to Lady Lister.

The President announced that he had been elected an Honorary Member of the Chemical, Metallurgical and Mining Society of South Africa.

The election of Christiaan Lodewyk Wicht to Membership was held over, owing to the absence of the necessary quorum.

Obituary:—

William Adam Tasker Jolly. Born in Edinburgh in 1878, and died in Cape Town on July 14, 1939. He was educated at George Watson's

College and Edinburgh University, where he obtained the degrees of M.B., Ch.B., and D.Sc. He was appointed an assistant to Dr. Sharpey Schafer, Professor of Physiology at Edinburgh University, in 1904. He was appointed Carnegie Research Fellow of the University of Edinburgh in 1908, and went to the Continent where he worked with Professor Einthoven at Leyden University. He returned to Edinburgh as Lecturer in Experimental Physiology, and in 1911 was appointed Professor of Physiology in the South African College. He was appointed Dean of the Faculty of Medicine in 1918 on the foundation of the University of Cape Town, and played a prominent part in the establishment and the development of the Medical School at Cape Town. In 1936 the University of Edinburgh conferred upon him the honorary degree of LL.D.

In Edinburgh and Leyden, Jolly showed his aptitude for research and had already published a number of papers when he came to South Africa. Here he carried on with his researches and made several outstanding contributions to our knowledge of electro-physiology. He was especially interested in electrical changes in the heart, in measurement of reflex time, and latterly in electrical changes accompanying retinal activity.

In addition to the active part he played in the advancement of knowledge, he did much to encourage scientific research in South Africa. He was Secretary of this Society from 1914 to 1927, and President from 1928 to 1932. He was also a Member of the Research Grant Board and the National Research Council and Board.

In his death South Africa loses a pioneer of medical education and an active worker in the interests of science. Physiology loses a research worker of outstanding merit.

Communications:—

"The Recent Archaeology of Gokomere, Southern Rhodesia," by J. F. Schofield.

"A Study of the Old Trade Beads of Nyasaland," by J. F. Schofield.

"Sparid Fishes from Portuguese East Africa, with a Note on the Genus *Gymnocranius* Klunzinger," by J. L. B. Smith.

A. J. H. Goodwin,
Hon. General Secretary.

Annual Meeting.

The Annual Meeting of the Society for the Election of Fellows was held on Wednesday, October 18, 1939, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The following were elected Fellows of the Society:—W. F. BARKER, B.Sc., Ph.D.; G. P. LESTRADE, M.A.; L. F. MAINGARD, D.Litt., L.-en-D.; M. A. POCOCK, B.Sc., Ph.D.; J. V. L. RENNIE, M.A., Ph.D.

ORDINARY MEETING.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of September 20, 1939, were passed.

Obituary Notices:—

Professor PAUL ANDRIES VAN DER BYL, M.A., D.Sc., F.R.S.S.Afr., 1888–1939.

In the death of Dr. P. A. VAN DER BYL South Africa has lost a very highly respected leader in Agriculture and Science, a most distinguished gentleman.

Born on May 25, 1888, in the district of Stellenbosch, he was the son of a well-known old Cape family which proudly traces its ancestry to one Gerrit van der Byl, who had settled at the Cape in 1664.

He was a student of the old Victoria College at Stellenbosch and graduated in 1909 with honours in Botany at the University of the Cape of Good Hope. After teaching for a short time in the Orange Free State he was appointed in 1911 to the newly created Division of Plant Pathology and Mycology at Pretoria, being subsequently placed in charge of the Natal Herbarium and the Plant Pathological Laboratory in Durban. During this period he obtained his M.A. and D.Sc. degrees of the University of the Cape of Good Hope.

In 1921 Dr. VAN DER BYL was appointed to the newly created Chair of Phytopathology and Mycology at the University of Stellenbosch, where he served on various committees, as Dean of the Faculty of Agriculture, and as a Member of the University Council.

Dr. VAN DER BYL was a clear and capable lecturer and was tireless in his efforts to bring the best to his students. Those attracted to post-graduate studies were aroused with real enthusiasm and greatly benefited by his stimulating guidance and his critical interpretation of scientific data, the results of which he lived to see reflected in the numerous contributions of those who were once his care. He was a keen collector of fungi and lichens and generally spent his leave on collecting trips. His comparatively large and valuable Herbarium has been bequeathed to the University of Stellenbosch, well provided for its future care.

In 1928 he succeeded Dr. Chas. Brain as Principal of the Stellenbosch Elsenburg College of Agriculture. With great thoroughness he directed agricultural activities in the area under his jurisdiction. His abilities were recognised and appreciated by the agricultural community, and it was at their special request that the Department of Agriculture appointed him Chairman of the Dried Fruit Board when this was established shortly before his sudden death from heart failure on July 25, 1939.

Dr. VAN DER BYL was the author of some fifty-four scientific contributions, was a Fellow of this Society and had served for some years on its Council.

A list of papers has been lodged in the Society's library.

Sir FREDERICK SPENCER LISTER, M.R.C.S., L.R.C.P., LL.D., F.R.S.S.Afr.

The sudden death of Sir SPENCER LISTER on September 6 has removed a notable South African of many activities.

Born in 1876 at Norwall, Notts, Lister received his medical education at St. Bartholomew's Hospital. In 1905 he became Medical Officer to the Premier Diamond Mines and in 1912 Medical Officer to the Rand Gold Mines.

He became specially interested in the problen of pneumonia in mine-workers, and extended the pioneer work of Sir Almroth Wright in immunising against this disease. In 1915 LISTER was appointed Research Scholar in Pneumonia at the South African Institute for Medical Research, and Research Bacteriologist to the Institute in 1917. He did important work in "typing" the strains of pneumococci prevalent on the Rand, and in 1920 was knighted for the part which he had played in the control of pneumonia.

In 1926 LISTER became Director of the South African Institute for Medical Research, where he proved himself a good administrator of quite unusual ability. He had an extensive knowledge of the problems of disease in South Africa and developed the Institute for the investigation of the more important of these.

Some sixteen papers by himself or in collaboration with others stand to his credit. A list of them has been lodged in the Society's library.

LISTER was an active member of the South African Medical Association (B.M.A.) and of the South African Medical Council. By his death these bodies are so much the poorer. He was also a member of certain Government Advisory Boards: the Union Council of Public Health; the Leprosy Advisory Board; the Research Grant Board; and was a Fellow of this Society.

His first wife died in 1919, and two years later he married again. He is survived by his widow, two sons, and two dauhgters.

Election to Membership:—CHRISTIAAN LODEWYK WICHT was elected a Member of the Society.

Nomination:—HERBERT BASIL SUTTON COOKE, proposed by C. VAN RIET LOWE, seconded by A. GALLOWAY.

Communications:—

"A Preliminary Account of Rainfall in Jonkershoek," by C. L. WICHT (communicated by A. J. H. GOODWIN).

"Reproduction in Hydrodictyon," by M. A. POCOCK.

LECTURE.—"The Geographic Setting of Current European History," by W. J. TALBOT.

A vote of thanks to the lecturer was moved by J. JACKSON, and seconded by R. H. COMPTON.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, November 15, 1939, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of October 18, 1939, were passed.

The President announced the following nominations to Council for 1940:—

Officers:—President, L. CRAWFORD; Hon. Treasurer, A. BROWN; Hon. Editor, Mrs. M. R. LEVYNS; Hon. Librarian, E. NEWBERY; Hon. Secretary, A. J. H. GOODWIN.

Continuing Members:—J. JACKSON, E. L. GILL, R. F. LAWRENCE, D. BURNETT, and L. VERWOERD.

Additional Members:—C. VON BONDE, B. F. SCHONLAND, H. E. WOOD, and S. H. HAUGHTON.

H. B. S. COOKE was elected to Membership of the Society.

H. D. ROBERTS, proposed by F. WALKER, seconded by W. J. TALBOT, was nominated for election to Membership.

Communications:—

"An Occurrence of Barite in an Iron-Ore Deposit from Namaqualand," by M. MATHIAS (communicated by A. W. ROGERS).

"Sillimanite-Corundum Rock: a Metamorphosed Bauxite from Namaqualand," by C. B. COETZEE (communicated by A. W. ROGERS).

"The Course of Crystallisation of Tholeiite Magma," by F. WALKER.

Tholeiite magma is a type of great abundance and world-wide distribution, occurring in the form of lavas and minor intrusions. It is a type, moreover, which assimilates little foreign material and its differentiation is therefore brought about largely by crystal fractionation. The study of its course of crystallisation is thus of considerable interest, and has been much advanced in recent years.

The present communication is an attempt to collate existing data and to find an explanation for certain discrepancies in them. It includes some new observations, and records a small but consistent difference between the average composition of lavas and sills in tholeiitic provinces.

"New Fossil Pig Remains from the Vaal River Gravels," by J. C. MIDDLETON SHAW and H. B. S. COOKE.

A. J. H. GOODWIN,
Hon. General Secretary.

REPORT OF THE HON. GENERAL SECRETARY FOR 1939.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the undermentioned papers were read:—

1. "A Surviving Fish of the Order Actinistia," by J. L. B. SMITH.
2. "Marine Fishes of Two Families and Two Genera new to South Africa," by J. L. B. SMITH.
3. "A hitherto Undescribed Industry from Mfongosi, Zululand," by D. D. NIDDRIE (communicated by J. SCHOFIELD).
4. "Some Observations on the Alleged Succession of Teeth in Snakes," by F. G. CAWSTON.
5. "Some Observations on the Arrangement of Teeth in Fishes," by F. G. CAWSTON.
6. "A Method of Correcting an Objective Noise-Meter for Use on Composite Tones," by R. GUELKE (communicated by B. L. GOODLET).
7. "New Fossil Elephant Remains from the Victoria Falls, Northern Rhodesia, and a Preliminary Note on the Geology and Archaeology of the Deposit," by H. B. S. COOKE and J. DESMOND CLARK.
8. "A Further Contribution to the Knowledge of the Vertical Distribution of Certain Intertidal Marine Gastropods in False Bay, South Africa," by G. J. BROEKHUYSEN.
9. "Three Mites Living on South African Millipedes," by R. F. LAWRENCE.
10. "Further Note on the Comparison of the Quartz Horizontal

Magnetometers Nos. 29 and 30," by K. W. SIMPSON and A. N. VAN WYK (communicated by A. OGG).

11. "The Stellenbosch Industry in the Wagenmakers Valley," by F. MALAN (communicated by A. J. H. GOODWIN).

12. "Early Pluviation and the Prepalaeolithic Pebble and Flake Artifacts of the Witwatersrand," by J. C. SMUTS, Jun. (communicated by A. J. H. GOODWIN).

13. "Stone Implements of the Eastern Limpopo Basin," by J. C. SMUTS, Jun. (communicated by A. J. H. GOODWIN).

14. "A Preliminary Note on the Gill-Rakers of Natal Fishes," by F. GORDON CAWSTON.

15. "A Stone Bead Industry of the Western Transvaal," by H. S. HARGER.

16. "A Living Coelacanthid Fish of Triassic Type from South Africa," by J. L. B. SMITH.

17. "A Projection Method of Mapping from Air Photographs," by H. G. FOURCADE.

18. "The Rôle of Sorbitol in the C-Metabolism of the Kelsey Plum. —I. Changes in Chemical Composition during Growth and Storage," by I. DONEN. II. "Relation of Carbohydrate and Acid Loss to CO_2 Production in Stored Plums," by I. DONEN and E. R. ROUX.

19. "Electro-Magnetic Induction in Water," by H. D. EINHORN (communicated by E. NEWBERY).

20. "Orientable Manifolds Constructed from a Solid Cube," by D. B. SUMNER (communicated by A. BROWN).

21. "The Recent Archaeology of Gokomere, Southern Rhodesia," by J. F. SCHOFIELD.

22. "A Study of the Old Trade Beads of Nyasaland," by J. F. SCHOFIELD.

23. "Sparid Fishes from Portuguese East Africa, with a Note on the Genus *Gymnocranius* Klunzinger," by J. L. B. SMITH.

24. "A Preliminary Account of Rainfall in Jonkershoek," by C. L. WICHT (communicated by A. J. H. GOODWIN).

25. "An Occurrence of Barite in an Iron-Ore Deposit from Namaqualand," by M. MATHIAS (communicated by A. W. ROGERS).

26. "Sillimanite-Corundum Rock: a Metamorphosed Bauxite from Namaqualand," by C. B. COETZEE (communicated by A. W. ROGERS).

27. "The Course of Crystallisation of Theoleiite Magma," by F. WALKER.

28. "New Fossil Pig Remains from the Vaal River Gravels," by J. C. MIDDLETON SHAW and H. B. S. COOKE.

LECTURE.—At the Ordinary Meeting of the Society on October 18, 1939, W. J. TALBOT gave a lecture on "The Geographic Setting of Current European History."

Volume XXVII, parts 1–3, of the Society's Transactions have been issued during the year.

William Francis Barker, Gerard Paul Lestrade, Lucien Fernand Maingard, Mary Agard Pocock, and John Vernon Lockhart Rennie were elected Fellows of the Society in 1939.

At the end of 1939 the number of Fellows was 83, Members 124. During the year seven new Members were elected, two Members resigned, and the name of one Member was struck off the list.

The deaths during the year of Professor W. A. Jolly, Sir Spencer Lister, Mr. G. T. Nicholson, Mr. H. E. V. Pickstone, and Professor P. A. van der Byl are recorded with regret. An obituary notice on Professor Jolly was read at the Ordinary Meeting of the Society on September 20, and notices on Sir Spencer Lister and Professor van der Byl were read at the Ordinary Meeting on October 18.

The thanks of the Council are due to the Union Government for a Grant of £400 for the year 1939–40. The Council's thanks are due, too, to the National Research Council and Board for a Grant of £60 towards publishing a paper by J. L. B. Smith, and to the Rhodes Trust for a Grant of £35 towards publishing a paper by E. H. Ashton.

The following gifts have been received by the Library during the year:—From Dr. Theodor Kluge, Berlin, Die Zahlbegriffe der Australier, Papua und Bantuneger nebst einer Einleitung ueber die Zahl, by the donor. Berlin, 1938, 305 pp., 6 maps, mimeographed; from R. A. Kennedy, London, The Laws of the Michelson-Morley Experiment, by the donor; from Miss M. Wilman, The Bantu Tribes of South Africa, Vol. 3, by Duggan-Cronin; from the Cape Natural History Club, *The Cape Naturalist*, No. 6, 1939; from R. W. Jack, Esq., Southern Rhodesia, Memoirs of the Dept. of Agriculture, No. 1; from Dr. William Proctor, Mount Desert Region Survey, part IV, Insecta; from Dr. C. L. Wicht, Zur Methodik des Durchforstungsversuchs (Thesis), by the donor; from Dr. L. F. Freed, The Social Aspect of Venereal Disease, by the donor; from A. H. Wallis, Esq., Mean Monthly and Annual Rainfall, South Africa, up to Dec. 31, 1925 (Graphs).

New exchanges have been arranged with the following institutions:—Entomological Society of Southern Africa, Pretoria; U.S.S.R. Society for Cultural Relations with Foreign Countries, Moscow; Kungl. Vetenskaps- och Vitterhetssamhalle, Göteborg, Sweden; Rijksmuseum van Naturlijke Historie, Leiden, Holland; National Research Council of Japan, Tokyo; Institut Français de l'Afrique Noire, Dakar, West Africa; Faculdade de Ciencias, Lisbon, Portugal; Gesellschaft für Erdkunde zu Leipzig.

All exchanges with institutions in enemy countries have been suspended for the duration of the war.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR, JANUARY 1 TO DECEMBER 31, 1939.

DR.

	£	s.	d.	£	s.	d.
Bank Balance at January 1, 1939				92	1	8
Subscriptions:						
Up to 1937	6	0	0			
1938	25	0	0			
1939 (Fellows)	46	0	0			
1939 (Town Members)	40	0	0			
1939 (Country Members)	55	0	0			
1939 (Life)	60	10	0			
1939 (Entrance)	8	0	0			
Advance payments	1	7	0			
				241	17	0
From Life Fund:						
Interest	17	0	3			
1/10th of Capital	57	13	0			
				74	13	3
Commissions on cheques				1	6	0
Sale of Publications				81	17	11
Sale of Reprints...				4	4	10
Grants:						
Union Government	400	0	0			
Rhodes Trust (Ashton on Sotho Diet) ...	35	0	0			
National Research Council and Board (Paper by Smith)	60	0	0			
				495	0	0
Miscellaneous				3	15	11
Interest:						
Rand Provident (Deposit)	16	0	0			
P.O. Savings Account	2	13	4			
G.H.S.B. (General Account)	7	1	7			
G.H.S.B. (Life Account)	13	2	6			
S.B.S.B.	0	1	4			
				38	18	9
				£1033	15	4

CR.

	£	s.	d.	£	s.	d.
Neill, Vol. XXVI, 4; XXVII, 1 and 2:						
Printing	361	12	0			
Postages and Charges	23	17	11			
Extra Reprints	14	0	9			
				399	10	8
Local Printing Account				38	14	6
Binding				38	13	11
Clerical Assistance and Messenger				49	0	0
Petty Cash				20	0	0
Commission and Bank Charges				3	11	5
Rent, etc.				78	6	0
Insurance				1	13	0
Miscellaneous				5	13	4
Lodged in Savings Account:						
P.O.S.B.	150	0	0			
G.H.S.B.	200	0	0			
				350	0	0
Interest credited to Account:						
P.O.S.B.	2	13	4			
G.H.S.B. (General)	7	1	7			
G.H.S.B. (Life)	13	2	6			
S.B.S.B.	0	1	4			
				22	18	9
Balance at December 31, 1939				25	13	9
				£1033	15	4

R. W. JAMES.
A. OGG.

ALEXANDER BROWN, Hon. Treasurer.

ASSETS AND LIABILITIES AT DECEMBER 31, 1939.

Assets.*	£	s.	d.	Liabilities.	£	s.	d.
Current Account Balance	25	13	9	Life Fund	609	11	4
P.O. Savings Bank	218	5	10	Neill, Vol. XXVII, Part 3	145	0	0
Standard Bank Savings Account	7	7	9	Neill, Vol. XXVII, Part 4 (Estim.)	170	0	0
Cape of Good Hope Savings Bank (General)	326	11	5	Neill (Additional)	100	0	0
Cape of Good Hope Savings Bank (Life)	364	1	4	Adv. Subs., etc.	1	7	0
Rand Provident Deposit	400	0	0	Excess of Assets over Liabilities	316	1	9
	£1342	0	1		£1342	0	1

* Exclusive of value of Library, Publications of the Society in stock, and other properties.

ALEXANDER BROWN, Hon. Treasurer.

We hereby certify that we have examined the above accounts of Revenue and Expenditure, and of Assets and Liabilities, that we have compared them with the books, vouchers, and other documents relative thereto, and that, in our opinion, these accounts set forth a correct description of the affairs of the Society.

R. W. JAMES.
A. OGG.

The following back numbers have been obtained during the year:—From the U.S. Coast and Geodetic Survey, Annual Reports, 1923–38, Special publications, Nos. 175–77, 179–216; from the Marine Biological Association of Great Britain, Plymouth, Journal, Vols. 1–23; from the Soc. Italiana di scienze naturali, Milan, Atti, Vol. 51, 1912—78, 1939; from the Rijksuniversiteit, Utrecht, Mededeelingen van het Botanisch Laboratorium, 1935–38.

As a result of a general ballot, the following changes in session were brought into force during the year:—

Statutes, Chapter I, 4: Second sentence is read:—"The session shall commence on the third Wednesday in March, and end on the third Wednesday in November. No Ordinary Meeting shall be held in July. The Anniversary Meeting shall be held in March, and the Annual Meeting in October at Cape Town."

Statutes, Chapter III, 6, to commence: "At the Ordinary Meeting of the Society in August . . ." Paragraph to end: "that election will take place at the Annual Meeting of the Society in October."

Statutes, Chapter VI, 1, to commence: "Council shall in the November preceding each Anniversary Meeting . . ."

During the year 86 volumes were sent to Chivers, of Bath, for binding.

116 periodicals were issued from the Society's library in 1939.

A. J. H. Goodwin,
Hon. General Secretary.

The Anniversary Meeting of the Society was held on Wednesday, March 20, 1940, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Annual Report of the Hon. General Secretary was read and passed.

The Annual Report of the Hon. Treasurer was read and passed.

The following were elected as Officers and Council for 1940:—President, L. Crawford; Hon. Treasurer, A. Brown; Hon. General Secretary, A. J. H. Goodwin; Hon. Editor of Transactions, Mrs. M. R. Levyns; Hon. Librarian, E. Newbery. Other Members of Council:—D. Burnett, E. L. Gill, S. H. Haughton, J. Jackson, R. F. Lawrence, L. Verwoerd, C. von Bonde, B. F. J. Schonland, H. E. Wood.

A vote of thanks was passed to the Auditors.

ORDINARY MEETING.

The Anniversary Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of November 15 were passed.

H. D. ROBERTS was elected to Membership of the Society.

The following were nominated for Membership:—L. F. FREED, proposed by D. M. WATT, seconded by L. H. WELLS; L. A. HURST, proposed by H. A. REYBURN, seconded by A. BROWN; W. J. LÜTJEHARMS, proposed by R. S. ADAMSON, seconded by E. L. STEPHENS.

Communications:—

"A Study of the Old Trade Beads of Nyasaland," by J. F. SCHOFIELD.

"Pottery from Bechuanaland and Rhodesia," by J. F. SCHOFIELD.

"New Fossil Pig Remains from the Vaal River Gravels," by J. C. MIDDLETON SHAW and H. B. S. COOKE.

"Observations on the Relation between Nucleolus and Chromosomes in Salivary Gland Nuclei of some South African Drosophilids," by G. ELOFF (communicated by C. J. VAN DER HORST).

"Some Observations on the Freshwater Mollusc commonly known as *Physopsis africana*, Krauss," by F. G. CAWSTON.

Identification of freshwater molluscs must be regarded largely as tentative until an adequate investigation has been made of the soft anatomy of the various species.

Krauss considered the shell of *Physopsis* as sufficiently distinctive to justify the creation of a new genus, directing special attention to the truncation of its columella.

This toothed-like projection and the tunnel it forms enables the species to be distinguished from allied shells. It also renders the shell liable to become detached from a moist leaf.

Identification may be assisted by consideration of the favourite food-supply of the various species.

Shells with ill-formed columella truncation are more common in Central Africa and are more closely allied to *Bulinus*.

A more careful study of the radula may assist to distinguish closely allied species as well as the larval trematodes which favour certain species more than others.

"The Effects of Extracts of Human Anterior Pituitary Glands on *Xenopus laevis*," by H. A. SHAPIRO.

(1) A substance capable of inducing ovulation in normal and in hypophysectomised Xenopus has been detected in alkali and in aqueous extracts of human anterior pituitary glands.

(2) The extract is oestrogenic in intact females, inducing hyperaemic activation of the oviducts and the cloacal labia.

(3) It induces release of spermatozoa in the male with the secretion of amphibian androgens which stimulate development of the male secondary sex characters, the arm pads.

(4) The active principle in the extract is either protein in nature or else closely associated with proteins.

(5) The possibility that there may be more than one active principle in the extract is discussed.

"The Vascular Anatomy of *Xenopus laevis*, Daudin," by N. MILLARD (communicated by T. A. STEPHENSON).

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, April 17, 1940, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The election to Membership of the following candidates was held over for the May Meeting:—

L. F. FREED, L. A. HURST, W. J. LÜTJEHARMS.

The President nominated J. JACKSON and S. H. HAUGHTON as Vice-Presidents of the Society for 1940.

Communication:—

"The Life-History of *Cyclograpsus Punctatus*, M. Edw: Breeding and Growth," by G. J. BROEKHUYSEN.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, May 15, 1940, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of April 17 were passed.

Miss M. A. POCOCK was admitted to Fellowship of the Society.

The following were elected to Membership of the Society:—L. F. FREED, L. A. HURST, W. J. LÜTJEHARMS.

The President announced that Council had adopted the following

resolution, submitted by R. S. ADAMSON, regarding the reading of papers at Ordinary Meetings:—

"That no paper presented to the Society be considered for publication until it has been read at a meeting of the Society in full or in abstract.

"In a case where neither the author nor the communicator is able to be present at a meeting, the author shall indicate to the Secretary who will read the paper.

"Exceptions to this procedure can only be made upon the express permission of the Council having been obtained before a meeting."

MARLOTH MEMORIAL.—The President announced that the Chemical Society has given a sum of £200 to the Royal Society for its administration in some form which would commemorate the Chemical and Botanical work of the late Dr. MARLOTH. This sum was in part collected by Members of the Chemical Society, and in part allocated from the funds of that Society.

Council has agreed to devote the interest on this sum to the publication of an outstanding Chemical or Botanical paper each year. A medallion of Dr. MARLOTH will be printed at the head of each paper selected.

The Chemical Society has endorsed this action, and has, in addition, promised to meet the cost of the die for the medallion. The thanks of this Society have been conveyed to the President of the Chemical Society.

Communications:—

"A Fossil Horse from Koffiefontein, O.F.S.," by L. H. WELLS.

"The Evolution of Middle Palaeolithic Technique in the Eastern Province," by P. W. LAIDLER.

"The Comparative Anatomy of the Tympanic Bulla and Auditory Ossicles, with a Note suggesting their Function," by J. A. KEEN and C. S. GROBBELAAR.

LECTURE.—"The Structure of Silicate Glasses," by P. C. CARMAN.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, June 19, 1940, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of May 15, 1940, were passed.

Obituary:—

The President read the following Obituary Notices:—

The death of Dr. T. R. SIM in July, 1938, terminated a long lifetime of hard work in the botany, horticulture, and forestry of South Africa. He was

born in Scotland in 1856 and came to this country in 1889 as Curator of Kingwilliamstown Botanic Garden. After three years he joined the Cape Forest Department, and in 1902 he became Conservator of Forests in Natal. During the next seven years he published The Forests and Forest Flora of the Cape of Good Hope, a book of remarkable usefulness, and The Forest Flora and Forest Resources of Portuguese East Africa. In 1909 he went into business in Maritzburg as nurseryman and forestry expert, and lived there until his retirement and a long period of failing health. During this time he published two further books on forestry—his Tree-planting in South Africa and his Native Timbers of South Africa. Other publications include the handy little volume on Flowering Trees and Shrubs for Cultivation in South Africa, and Tree-planting in Natal.

SIM's work was not confined to trees. His book on The Ferns of South Africa is the only comprehensive study of the subject. Most remarkable of all is his large monograph on "The Bryophyta of South Africa," published by the Royal Society of South Africa (Transactions, 1925), a monument of energy and persistence, in spite of formidable difficulties. A characteristic of his published work, whether on trees, ferns, or mosses and liverworts, is the copious line illustrations from his own hand.

He was a pioneer, exploring difficult and almost untrodden ways, and so successful and useful are his achievements that it will be many long years before they are superseded—by new works for which he provided the foundations.

The death on April 24, 1940, at the age of seventy-nine, of Professor S. SCHÖNLAND marks the passing of a botanist of international repute. The Society also loses one of its oldest members. SCHÖNLAND was elected a Member of the South African Philosophical Society in 1890, and on the foundation of the Royal Society in 1908 was elected a Fellow.

Educated at the Universities of Berlin and Kiel, SCHÖNLAND as a young man was assistant to the Professor of Botany at Berlin and later at Oxford. He came to South Africa in 1889 and shortly after was appointed Director of the Albany Museum. In 1904 he was appointed as the first Professor of Botany at Rhodes University College, a position he held until his retiral in 1925.

Throughout his life SCHÖNLAND was engaged on original work. His main interests lay in systematic botany, to which he made many and valuable contributions. His botanical work, however, also extended over many other aspects; he published papers on plant distribution, ecology, biology, and practical problems such as weed eradication. His publications made a long list, from which it is not possible here to select individual items for mention. In addition to his botanical work, SCHÖNLAND made important contributions to South African archaeology.

Schönland was much interested in education, and he played a big part in the building up of the University of South Africa and especially of Rhodes University College.

Communication:—

"Simultaneous Measurement of Valve Constants," by N. H. Roberts (communicated by E. Newbery).

Discussion.—"Physics in Everyday Life," opened by H. D. Einhorn.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, August 21, 1940, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. Crawford, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of June 19 were passed.

The President announced that he had been made an Honorary Member of the Chemical, Metallurgical and Mining Society.

The President read the following recommendations, for Election to Fellowship, from Council:—

Albert John Hesse, proposed by S. H. Skaife, T. A. Stephenson, E. L. Stephens, and R. S. Adamson; John Cecil Middleton Shaw, proposed by R. A. Dart, H. H. Paine, C. van Riet Lowe, and John Phillips; Frederick Walker, proposed by R. W. James, A. Ogg, R. S. Adamson, and H. A. Reyburn; Laurence Chisholm Young, proposed by R. W. James, A. Ogg, R. S. Adamson, and H. A. Reyburn.

The following was nominated for Election to Membership of the Society:—

Douglas L. Scholtz, proposed by F. Walker, seconded by A. R. E. Walker.

Presidential Address.—"Edward Waring: Eighteenth-Century Mathematician."

Communications:—

"Factorial Analysis and School Subjects," by H. A. Reyburn and J. G. Taylor.

"The Genus *Gymnocranius* Klunzinger, with a Note on *Nemipterus delagoae*, nom. nov." by J. L. B. Smith.

A. J. H. Goodwin,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, September 18, 1940, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of August 21, 1940, were passed.

The Election of DOUGLAS L. SCHOLTZ to Membership was postponed until the October Meeting.

The following was nominated to Membership of the Society:—DOUGLAS HEY, proposed by C. L. WICHT, seconded by A. J. H. GOODWIN.

The President announced with regret the death of Dr. C. L. HERMAN, for many years a Member of the Society.

Communications:—

"A Consideration of the Development of Denticles in its Relation to the Supposed Succession of Teeth in Skates," by F. GORDON CAWSTON.

It has been taken for granted that the alleged succession of teeth in *Selachii* can be applied to *Batoidei*, and that vertical succession, as readily demonstrated in fishes, has been replaced by a forward revolving of the tooth-bearing area continuing throughout life. Examination of the surface of gill-arches shows that replacement of rakers is uncommon but occurs by vertical succession, and that denticles on these arches in *Selachii* are also replaced by new ones forming at their base, rather than by a constant revolving of the surface.

In portions of the jaw of some *Batoidei* the teeth resemble the denticles very closely, especially at the tooth-border and here the teeth are probably being added to throughout life. Under such circumstances succession is vertical, new teeth developing between the bases of those which have been shed.

New teeth-formation is evident at the foremost portion of the tooth-bearing area of skates as at its hindermost border. Similar tooth-formation is seen towards the angle of the jaw, it being the central portion which contains the largest teeth in both skates and rays. Though worn, these central teeth would not resemble the foremost teeth, as seen microscopically.

Injured jaws lessen a skate's power of resisting attacks and specimens are difficult to obtain, but abnormalities of the jaws do not justify application of the theory of succession to *Batoidei*.

"Ancient Pottery from the Belgian Congo," by P. W. LAIDLER.

"Earthenware Objects from Southern Rhodesia," by P. W. LAIDLER.

"Some Ecological Factors Affecting the Fertility of Trout Eggs at the Jonkershoek Trout Hatchery," by D. HEY (communicated by A. J. H. GOODWIN).

A. J. H. GOODWIN,
Hon. General Secretary.

The Annual Meeting of the Society for the Election of Fellows was held on Wednesday, October 16, 1940, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The following were duly elected Fellows of the Society:—A. J. HESSE, J. C. M. SHAW, F. WALKER, and L. C. YOUNG.

ORDINARY MEETING.

The Annual Meeting was followed by an Ordinary Meeting.

Business:—

The Minutes of the Ordinary Meeting of September 18, 1940, were passed.

The following were elected to Membership:—DOUGLAS HEY and DOUGLAS L. SCHOLTZ.

The President congratulated the Royal Observatory on the success of the Eclipse Expedition.

L. C. YOUNG was admitted to Fellowship of the Society.

Communications:—

"A New World-Picture," by L. H. STABELL (communicated by A. J. H. GOODWIN).

In trying to make a new world-picture, the author first builds up a new atomic picture. This atomic picture is then fitted into the picture of the stars.

By picturing the atom as a "pulsating-rotating sphere" it can be compared with the picture of the heavenly bodies as pulsating stars in a pulsating universe, which also are in rotation, so that we get the same picture of the smallest atom as of the largest universe.

The further scope of the theory is to connect the wave-theory of the electro-magnetic radiation with the quantum theory of rays, by supposing that these waves and rays both are a longitudinal wave-motion which originates in a vibrating-rotating atom.

"Further Excavations (1939) at the Mumbwa Caves, Northern Rhodesia," by J. DESMOND CLARK (communicated by C. VAN RIET LOWE).

"The Vitamins," by L. P. BOSMAN.

A. J. H. GOODWIN,
Hon. General Secretary.

An Ordinary Meeting of the Society was held on Wednesday, November 20, 1940, at 8.15 p.m., in the Board Room of the South African Association, Church Square, Cape Town.

The President, Dr. L. CRAWFORD, was in the Chair.

Business:—

The Minutes of the Ordinary Meeting of October 16, 1940, were passed.

J. V. L. RENNIE and A. J. HESSE were admitted as Fellows of the Society.

The President announced the deaths of E. T. MELLOR, Fellow, and J. BURTT-DAVY, Hon. Life Fellow, of this Society.

The President announced the following as Council's recommendations for Council for 1940:—

President, L. CRAWFORD; Hon. Treasurer, *R. W. JAMES; Hon. General Secretary, A. J. H. GOODWIN; Editor, Mrs. M. R. LEVYNS; Librarian, E. NEWBERY. Additional Members:—*G. ARNOLD, *W. F. BARKER, A. BROWN, L. GILL, J. JACKSON, *M. RINDL, L. VERWOERD, C. VON BONDE, and H. E. WOOD.

* New Members.

Retiring Members are D. BURNETT, R. F. LAWRENCE, B. F. J. SCHONLAND, S. H. HAUGHTON.

Communications:—

1. "Growth Effector Principles in Urine." 2. "The Protein Content of the Serum Embryo Extract." 3. "Estimation of the Mitosis Rate in Tissue Culture," by W. S. S. LADELL.

"An Original Development in Bantu Domestic Ornamentation," by P. W. LAIDLER.

The writer describes certain changes in the method of building the native hut in the Transkei, which are the result of contact with the European, and the development of an original method of denoting ownership through ornamentation of door and window surrounds.

"A Bantu Reversion to Stone Age," by P. W. LAIDLER.

The writer describes the result of deforestation in the Transkei, its effects upon domestic economy by loss of wood, and the replacement of wood-working by stone-working for the production of certain domestic utensils, which is rendered possible by European contacts.

DISCUSSION.—"Colchicine: Important Genetic Applications of a Known Organic Chemical," introduced by A. J. H. GOODWIN.

Obituary:—

EDWARD THOMAS MELLOR (1868–1940) was born in Manchester and educated at the Manchester Grammar School and the Victoria University, where he studied under Boyd-Dawkins; he did very great service to South

Africa by his work on the Witwatersrand formation and the Coal Measures, as well as on other formations of less obvious economic interest though important in the structure of the country. To him, as Geologist on the staff of the Geological Survey of the Transvaal, was assigned the task of reducing to order the stratigraphical succession in the Witwatersrand System, knowledge of the lower half of which was especially uncertain before his work.

Appointed to the Geological Survey in 1902, he began detailed work on the Rand in January, 1910, and his series of papers, reports and maps was completed in 1917, the year after he had left the Survey to join the Central Mining and Investment Corporation as Consulting Geologist. It was characteristic of MELLOR that at a very early stage in his official career he insisted on the geological survey of the Rand being left until he and others on the staff had obtained a rather extensive knowledge of the rocks and structures of less topical interest beyond the Rand itself; and it was no less characteristic that he got his way. Not only the economic, but also the commercial, importance of the work made it advisable that particular care should be taken in his observations and that hypothesis should be confined to the narrowest limits. Probably the most important result of his work on the Rand was the proof that the apparent variation in the Lower Witwatersrand beds over their main outcrop of 50 miles is due to the local elimination at the surface, or repetition, of parts of the whole succession by strike-faults, and to variation of thickness in some groups of beds owing to the effects of pressure on rocks differing much in strength, all of which had caused much confusion. This might seem to be a slight result of so much labour, but it was of the greatest importance in the exploration of the goldfield, and its demonstration has saved untold waste of energy. The experience of the last twenty-three years has proved the soundness of Dr. MELLOR's work. Of course, the work done by many mining men and geologists since 1917 has greatly increased our knowledge of the Witwatersrand formation, especially of the distribution of the conglomerates on certain horizons, of petrographic detail, and of the structure of some "sub-outcrop" areas obtained by new methods, such as magnetic survey; but his work is the sure foundation on which all this has been built.

At the time MELLOR began work on the Rand, mining and prospecting had shown that almost all the gold won there came from conglomerates, so the origin of the gold was a question of theoretical rather than practical interest. Opinion on the question had varied, though it was preponderately on the side of extraneous origin by means of solutions passing through the more permeable beds. After much experience he concluded that the gold was originally in the conglomerates, though altered in form, as was much of the rest of the rock. This view is generally accepted to-day.

MELLOR took the degree of B.Sc. (London) in 1895, and D.Sc. (London) in 1909, was a Fellow of the Geological Society of London and of the Royal Society of South Africa; he was President of the Geological Society of South Africa in 1911 and of the South African Association for the Advancement of Science in 1926; he was awarded the Goldfields Premium and Medal of the Institute of Mining and Metallurgy in 1916, and the Draper Memorial Medal of the Geological Society of South Africa in 1939.

Dr. MELLOR was twice married, leaving by his first wife two sons now engaged in engineering.

JOSEPH BURTT-DAVY, M.A. (Oxon.), Ph.D. (Cantab.), F.L.S., who died on August 20, 1940, was born in 1870 at Findern, Derby. After working as an assistant at Kew during 1891–92, he went to America where he held various botanical posts, at first in California, then in the Department of Agriculture at Washington, up to 1903, when he was appointed Agrostologist and Botanist in the Department of Agriculture at Pretoria. He retired in 1913 to take up farming in the Transvaal, continuing until 1918 when he left South Africa for Kew to work on his Flora of the Transvaal and Swaziland, for the purposes of which, during his stay in the Transvaal, he had accumulated large collections, now mostly in the National Herbarium at Pretoria. On publishing the first part of the Transvaal Flora in 1936 he took up the post of Lecturer in Forest Botany and Ecology at the Imperial Forestry Institute, Oxford. While there he brought out the second part in 1932, and had prepared most of part 3, when he gave up the work for want of spare time, but mainly on account of the heavy costs of preparation and printing, towards which the Royal Society of London had contributed £75.

BURTT-DAVY's other publications include the accounts of the glumaceous families for Jepson's Flora of Middle Western California and numerous floristic, forestal, and ecological papers, besides a large treatise on "Maize, its History, Cultivation, Handling, and Uses" which was published in South Africa, official reports of enduring value illustrated by his gifted, devoted, American wife, and a mass of contributions on economic botany published in the Transvaal Agricultural Journal or the Agricultural Journal of the Union of South Africa.

BURTT-DAVY was elected a Fellow of the Royal Society of South Africa in 1905. He was a strenuous worker who did not spare himself. His affable character endeared him to many friends.

With acknowledgments to "Nature" for some of the information.

A. J. H. GOODWIN,
Hon. General Secretary.

REPORT OF THE HON. GENERAL SECRETARY FOR 1940.

Eight Ordinary Meetings, the Annual Meeting, and the Anniversary Meeting were held during the year, and the undermentioned papers were read:—

1. "A Study of the Old Trade Beads of Nyasaland," by J. F. SCHOFIELD.

2. "Pottery from Bechuanaland and Rhodesia," by J. F. SCHOFIELD.

3. "New Fossil Pig Remains from the Vaal River Gravels," by J. C. MIDDLETON SHAW and H. B. S. COOKE.

4. "Observations on the Relation between Nucleolus and Chromosomes in Salivary Gland Nuclei of some South African Drosophilids," by G. ELOFF (communicated by C. J. VAN DER HORST).

5. "Some Observations on the Freshwater Mollusc commonly known as *Physopsis africana*, Krauss," by F. G. CAWSTON.

6. "The Effects of Extracts of Human Anterior Pituitary Glands on *Xenopus laevis*," by H. A. SHAPIRO.

7. "The Vascular Anatomy of *Xenopus laevis* Daudin," by N. MILLARD (communicated by T. A. STEPHENSON).

8. "The Life-History of *Cyclograpsus Punctatus*, M. Edw.: Breeding and Growth," by G. J. BROEKHUYSEN.

9. "A Fossil Horse from Koffiefontein, O.F.S.," by L. H. WELLS.

10. "The Evolution of Middle Palaeolithic Technique in the Eastern Province," by P. W. LAIDLER.

11. "The Comparative Anatomy of the Tympanic Bulla and Auditory Ossicles, with a Note suggesting their Function," by J. A. KEEN and C. S. GROBBELAAR.

12. "Simultaneous Measurement of Valve Constants," by N. H. ROBERTS (communicated by E. NEWBERY).

13. "Factorial Analysis and School Subjects," by H. A. REYBURN and J. G. TAYLOR.

14. "The Genus *Gymnocranius* Klunzinger, with a Note on *Nemipterus delagoae*, nom. nov." by J. L. B. SMITH.

15. "A Consideration of the Development of Denticles in its Relation to the Supposed Succession of Teeth in Skates," by F. GORDON CAWSTON.

16. "Ancient Pottery from the Belgian Congo," by P. W. LAIDLER.

17. "Earthenware Objects from Southern Rhodesia," by P. W. LAIDLER.

18. "Some Ecological Factors Affecting the Fertility of Trout Eggs at the Jonkershoek Trout Hatchery," by D. HEY (communicated by A. J. H. GOODWIN).

19. "A New World-Picture," by L. H. STABELL (communicated by A. J. H. GOODWIN).

20. "Further Excavations (1939) at the Mumbwa Caves, Northern Rhodesia," by J. DESMOND CLARK (communicated by C. VAN RIET LOWE).

21. "The Vitamins," by L. P. BOSMAN.

22. "Growth Effector Principles in Urine—The Protein Content of the Serum Embryo Extract—Estimation of the Mitosis Rate in Tissue Culture," by W. S. S. LADELL.

23. "An Original Development in Bantu Domestic Ornamentation," by P. W. LAIDLER.

24. "A Bantu Reversion to Stone Age," by P. W. LAIDLER.

LECTURE.—At the Ordinary Meeting of the Society on May 15, P. C. CARMAN gave a lecture on "The Structure of Silicate Glasses."

DISCUSSIONS.—At the Ordinary Meeting of the Society on June 19, a discussion was held on the subject "Physics in Everyday Life," opened by H. D. EINHORN.

At the Ordinary Meeting of the Society on November 20, a discussion was held on the subject "Colchicine: Important Genetic Applications of a Known Organic Chemical," introduced by A. J. H. GOODWIN.

The PRESIDENTIAL ADDRESS on "Edward Waring: Eighteenth-Century Mathematician" was delivered by Dr. L. CRAWFORD on August 21.

Vol. XXVIII, parts 1 to 3 of the Society's Transactions have been published during the year.

ALBERT JOHN HESSE, JOHN CECIL MIDDLETON SHAW, FREDERICK WALKER, and LAURENCE CHISHOLM YOUNG were elected Fellows of the Society in 1940.

At the end of 1940 the number of Fellows was 84, Members 115. During the year six new Members were elected, four Members resigned, and the name of one Member was struck off the list.

The deaths during the year of Dr. J. BURTT-DAVY, Dr. C. L. HERMAN, and Dr. E. T. MELLOR are recorded with regret.

The thanks of the Council are due to the Union Government for a grant of £400 for the year 1940–41. The Council's thanks are due, too, to the University of the Witwatersrand for a grant of £20 towards publishing a paper by R. A. DART, to the National Research Council and Board for a grant of £50 towards publishing a paper by N. A. H. MILLARD, and to the Vice-Chancellor's Committee for £10 towards a paper by D. B. SUMNER.

New exchanges have been arranged with the following institutions:— Escuela Nacional de Ciencias, Mexico, D.F.; Société Mathématique, Amsterdam (since suspended).

The following gifts have been received by the Library during the year:— From Miss WILMAN, Rutherford, The New Alchemy, 1937; from the K. Svenska Vetenskapsakademien, K. Svenska Vetenskapsakad, Förhistoria, Grundlaggning och första Organisation; do., Some Notes on the Royal

Swedish Academy of Science, by Arne Holmberg (in English and Swedish); from the Mazoe Experimental Station, Annual Report for 1937; from the Conférence Romaine des Missions Catholiques d'Afrique, Africanae Fraternae Ephemerides Romanae, No. 20–21, Mars-Juin, 1940.

Reprints have been received from K. H. Barnard, F. G. Cawston, L. F. Freed, and W. D. Francis.

The following back numbers have been received from the U.S. Geological Survey, Washington, during the year: Bulletins, Nos. 885–917A (1938–39) (incomplete); Water-Supply Papers, Nos. 796G–861 (1939) (incomplete); Professional Papers, Nos. 183–191 (1936–39) (incomplete).

During the year, sets of cards analysing the contents of the Johns Hopkins University Studies have been bought from the Library of Congress, Washington. These cards will be stamped "Royal Society of South Africa," and filed in the Author and Subject Catalogues of the University of Cape Town Library.

53 periodicals were issued from the Society's Library during 1940.

No periodicals have been sent for binding this year, as all binding, except for urgent matter, is being allowed to accumulate until after the war.

Following the precedent of the last war, Council has decided that in the case of a Member or Fellow on active service, no payment will be asked and no publications sent. If the Member or Fellow resumes membership after the war, back numbers will be supplied free. In the case of a Life Member or Fellow, publications will be supplied as usual. It is imperative that Members or Fellows going on active service should notify the Society as to their wishes.

A. J. H. Goodwin,
Hon. General Secretary.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR, JANUARY 1 TO DECEMBER 31, 1940.

DR.

	£ s. d.	£ s. d.
Bank Balance at January 1, 1940		25 13 9
Subscriptions:		
Up to 1938	16 0 0	
1939	21 0 0	
1940 (Fellows)	43 18 6	
1940 (Town Members)	39 17 0	
1940 (Country Members)	47 0 0	
1940 (Life Subscriptions)	46 0 0	
1940 (Entrance Fees)	5 0 0	
1940 (Advance Payments)	2 13 6	
		221 9 0
Drawn from Life Fund:		
Interest	21 2 6	
1/10th of Capital	58 16 6	
		79 19 0
Commissions on Cheques		0 19 6
Sales of Publications		30 5 10
Sales of Extra Reprints		35 4 4
Grants:		
University of the Witwatersrand (R. A. Dart)	20 0 0	
Union Government (Annual)	400 0 0	
Vice-Chancellors' Committee (D. B. Sumner)	10 0 0	
National Research Council and Board (Mrs. N. Millard)	50 0 0	
		480 0 0
Miscellaneous		1 8 6
Interest:		
Rand Provident	16 0 0	
P.O. Savings Bank	4 4 0	
Good Hope Savings Bank (General Account)	11 8 2	
Good Hope Savings Bank (Life Account)	10 12 9	
Standard Bank Savings Bank	0 2 8	
		42 7 7
		£917 7 6

CR.

	£ s. d.	£ s. d.
Neill, Vols. XXVII, 3 and 4; XXVIII, 1:		
Printing	409 6 10	
Extra Reprints	31 18 11	
Postages, Drafts, etc.	27 0 1	
		468 5 10
Local Printing Account		32 9 0
Binding		29 18 6
Clerical Assistance, etc.		49 0 0
Petty Cash		18 0 0
Commission and Bank Charges		3 5 3
Rent		4 4 0
Insurance		1 5 0
Miscellaneous		21 9 10
Interest credited to Accounts:		
Post Office Savings Bank	4 4 0	
Good Hope Savings Bank (General Account)	11 8 2	
Good Hope Savings Bank (Life Account)	10 12 9	
Standard Bank Savings Bank...	0 2 8	
		26 7 7
Bank Balance at December 31, 1940		263 2 6
		£917 7 6

R. S. ADAMSON.
R. W. JAMES.

ALEXANDER BROWN, Hon. Treasurer.

ASSETS AND LIABILITIES AT DECEMBER 31, 1940.

Assets.*	£	s.	d.	Liabilities.	£	s.	d.
Current Account Balance ...	263	2	6	Life Fund ...	583	14	4
Post Office Savings Bank ...	222	9	10	Neill, Vol. XXVII, Part 2 ...	149	3	6
Standard Bank Savings Bank ...	7	10	5	Neill, Vol. XXVIII, Parts 3, 4 (Estimate) ...	340	0	0
Good Hope Savings Bank (General) ...	337	19	7	Additional for Publications ...	100	0	0
Good Hope Savings Bank (Life) ...	294	15	1	Advance Subscriptions ...	2	13	6
Rand Provident Deposit ...	400	0	0	Binding Allocation Unspent ...	20	1	6
Interest not deposited ...	8	0	0	Bills Unpaid ...	39	0	0
				Excess of Assets over Liabilities ...	299	4	7
	£1533	17	5		£1533	17	5

* Exclusive of value of Library, Publications of the Society in stock, and other properties.

ALEXANDER BROWN, Hon. Treasurer.

We hereby certify that we have examined the above accounts of Revenue and Expenditure, and of Assets and Liabilities, and have compared them with the books, vouchers, and other documents relating thereto, and that in our opinion these accounts set forth a correct description of the affairs of the Society.

R. S. ADAMSON.
R. W. JAMES.

PRESIDENTIAL ADDRESS.

EDWARD WARING, EIGHTEENTH CENTURY MATHEMATICIAN.

[ABBREVIATED.]

By L. CRAWFORD, M.A., D.Sc., LL.D., F.R.S.E.

(Read August 21, 1940.)

In making up this address the writer acknowledges special indebtedness to the books: "Cambridge in the Eighteenth Century," by D. A. Winstanley; "Unreformed Cambridge," by D. A. Winstanley; "Some famous Problems of the Theory of Numbers and in particular Waring's Problems," an inaugural lecture by G. H. Hardy; "The Theory of Numbers," by Hardy and Wright.

The professors at the University of Cambridge in the eighteenth century have incurred the indignant scorn of posterity, and for the most part they have deserved it. As a class they stand condemned of scandalously neglecting their duties, of failing to advance knowledge by study and research, and even sometimes of being unacquainted with the subjects they had undertaken to teach.

One of the difficulties felt by those who directed the affairs of the University arose from the constitution of the University; part of it consisted of the code of statutes granted by Queen Elizabeth in 1570, and, while the University could alter its own statutes or ordinances, it could not alter that code in any way although it became out of date and a barrier to progress. The University could have petitioned the Crown to alter the code, but instead it chose the easier way of disregarding statutes which it found inconvenient or inexpedient. By the eighteenth century this habit of law-breaking had much increased. The professors in many cases adopted this habit and evaded the duties laid down by statute or regulation. Some considered it unnecessary to carry out the duty of lecturing, and pleaded either that they could not get an audience if they did or that the undergraduates were fully provided for by lectures at their colleges. When this evasion of duty became common, it became natural for many to look upon the professorships as sinecures, and for elections to chairs to become scrambles by the electors to appoint personal friends, quite apart from knowledge of the subject of the chair under consideration.

The Lucasian professorship of Mathematics was founded in 1663 by Henry Lucas, M.P. for the University, and was endowed with an estate in Bedfordshire. The annual stipend was £100; the professor was to lecture once a week during term and be accessible to students who wished to consult him; for every omission to lecture he was to be fined 40s. He was forbidden to accept a cure of souls and was compelled to reside in the University, but he was permitted to hold a college fellowship and that without taking orders.

The holders of the chair, appointed in the eighteenth century, who followed Newton (he resigned in 1702) were: 1702, William Whiston; 1711, Nicholas Sanderson; 1739, John Colson; 1760, Edward Waring; 1798, Isaac Milner.

Only one of these is known as a mathematician, Edward Waring, Senior Wrangler in 1757. On the day of Colson's death, Waring wrote to the Chancellor, the Duke of Newcastle, stating that he proposed to be a candidate for the chair and asked his Grace's support. At that time Waring was only twenty-five, a junior Fellow of Magdalen College, and not yet of standing to take the M.A. degree, without which he could not have been appointed to the chair. Newcastle made no promise, but asked the Vice-Chancellor to find out Waring's status; he interviewed Dr. Smith, the Master of Trinity (who later founded the Smith's Prizes), and reported to Newcastle as follows: "Having seen part of the book which Mr. Waring is going to publish, he (Dr. Smith) says that Mr. Waring shows a deal of fire and some invention, but seems to have given too little attention to the proper manner of expressing his thoughts, and is therefore sometimes not easy to be understood. This, however, he considers as a fault that time will probably correct, and as the young man has discovered an earnest desire to excell, it is likely that he will improve himself into a degree of eminence." This was accepted as sufficient, and it was agreed that Waring should get a Master of Arts degree by royal mandate and so be eligible for the chair. Waring had already gained in the University a reputation as a mathematician, and he circulated the first chapter of his Miscellanea Analyticae in order that the electors and the University at large might judge of the nature of his pursuits and his qualifications for the high office which he solicited. Two other candidates came forward, William Ludlam and Francis Maseres. Ludlam was considerably senior to Waring, but as a mathematician was distinctly inferior. Maseres had left Cambridge and was in London at the Bar; too late to gain support he announced his intention, if elected, to reside in Cambridge, and he withdrew from the contest. To some of the electors it appeared a dangerous precedent to appoint so young a man as Waring. Winstanley describes the contest as between the elderly competent teacher and the young man

of genius. In January 1760 the election took place, and Waring was elected by 6 votes to 5.

It would be pleasant to say that in his thirty-eight year tenure of the chair Waring carried out its duties with zeal, and that he was a worthy successor to Newton. But the statement would be wholly untrue, he systematically neglected many of its duties and evaded many of its obligations. He wrote his books and he was an excellent examiner for the Smith's Prizes, but that was all. For the major part of his tenure of office he did not reside at Cambridge, and there is no evidence that he ever lectured or was accessible to students.

Waring was elected F.R.S. in 1763, but withdrew in 1765. By then he was studying medicine, and in 1767 he took the degree of M.D. at Cambridge. In 1770 he was a physician at Addenbrooke's Hospital, later he practised for a time at St. Ives, Huntingdon, but he does not seem to have been a successful doctor. In any case he did not need to practise, he had the income of his chair and a handsome patrimony. In 1776 he married a lady from Shrewsbury and went to live there, but later they lived on his estate in Shropshire, and there he died on August 15, 1798. A strange compound of vanity and modesty, towards the end he sank into religious melancholy approaching insanity.

He boasted that he had given somewhere between three and four hundred new propositions in mathematics of one kind or another, considerably more than had been given by any other English writer, but he confessed he never could hear of any reader in England, out of Cambridge, who took the pains to read and understand his writings. His books were:—

1. Miscellanea Analyticae de Æquationibus Algebraicis et Curvarum Proprietatibus, 1762.
2. Meditationes Algebraicae, 1770; 3rd edition, revised and enlarged, 1782.
3. Proprietates Algebraicarum Curvarum, 1st edition 1762, 2nd edition, 1772.
4. Meditationes Analyticae, 1776: 2nd edition, with additions, 1785.
5. On Principle of translating Algebraic Quantities into Probable Relations and Annuities, 1792.
6. Essay on principles of Human Knowledge, written 1794 but never published, copies given privately.

Of these books three are in the Muir Mathematical Library (Cape Town): a copy of No. 2, 3rd edition; another copy of the same bound with a copy of No. 3, 2nd edition; and a copy of No. 4, 2nd edition.

These books are now laid aside, and Waring's name would have been

forgotten like the other holders of the Lucasian Chair in the eighteenth century but for statements in Theorem 47 of the 3rd edition of the Meditationes Algebraicae, 1782:—

5. Omnis integer numerus est quadratus; vel e duobus, tribus vel quatuor quadratis compositus.
9. Omnis integer numerus vel est cubus; vel e duobus, tribus, 4, 5, 6, 7, 8 vel novem cubis compositus; est etiam quadrate-quadratus; vel e duobus, tribus &c. usque ad novemdecim compositus & sic deinceps.

[5. Every integral number is a square; or is made up of the sum of two, three or four squares.
9. Every integral number is a cube; or is made up of the sum of two, three, 4, 5, 6, 7, 8 or 9 cubes: is also a fourth-power; or is made up of the sum of two, three &c. up to nineteen fourth-powers, and so on.]

Professor Hardy, who has returned to Cambridge as Sadlerian Professor of Mathematics after a short stay at Oxford as Savilian Professor of Geometry, said in his inaugural lecture at Oxford:—

"Waring advanced no argument of any kind in support of his assertion, and it is in the highest degree unlikely that he was in possession of any sort of proof. I have no desire to detract from the reputation of a man who was a very good mathematician, if not a great one, and who held a very honourable position in a University which not even Oxford has persuaded me entirely to forget. But there is a tendency to exaggerate the profundity implied by the enunciation of a theorem of this particular kind. We have seen this even in the case of Fermat, a mathematician of a class to which Waring had not the pretensions to belong, whose notorious assertion concerning Marsenne's numbers has been exploded, after the lapse of over 250 years, by the calculations of the American computer, Mr. Powers. No very laborious computations would be necessary to lead Waring to a highly plausible speculation, which is all I take his contribution to the theory to be; and in the Theory of Numbers it is singularly easy to speculate, though often terribly difficult to prove, and it is only proof that counts."

The general problem is: take $n = x_1^k + x_2^k + \ . \ . \ . \ + x_s^k$. Question (i) is, for every n and given k, is there an s, $g(k)$, independent of n, such that the equation is true? Question (ii) is: what is the lowest value of this $g(k)$?

Waring implies that the answer to (i) is yes, and that the answer to (ii) is $g(2)=4$, $g(3)=9$, $g(4)=19$. But it was not till 1909 that it was proved

that the answer to (i) was yes, and the proof was an existence proof and gave no clue to the answer to (ii).

$G(k)$ is defined as the least value of s for given k, for which it is true that all numbers with at most a finite number of exceptions are represented by the sum of s kth powers.

It has been proved that $g(2)=4$ and $G(2)=4$. No number of the form $8b+7$ can be expressed as the sum of three squares, and there are an infinite number of such numbers, hence $G(2)$ cannot be 3.

Take $k=3$. Whatever numbers x_1, x_2, x_3 are, $x_1^3+x_2^3+x_3^3$ is never of form $9m+4$ or $9m+5$, and there are an infinite number of such numbers,

$$\therefore\ G(3) \geqslant 4 \quad \text{and also} \quad g(3) \geqslant 4.$$

On proceeding to tabulate the numbers, it is found that for numbers up to 40,000 only two, 23 and 239, require 9 cubes. $23=2\cdot2^3+7\cdot1^3$; $239=2\cdot4^3+4\cdot3^3+3\cdot1^3$. It has been proved that the number requiring 9 cubes is finite, and it is most probable that these are the only ones. 15 numbers only require 8: 15, 22, 50, 114, 167, 175, 186, 212, 231, 238, 303, 364, 420, 428, 454. [$212=2\cdot4^3+3\cdot3^3+3\cdot1^3$; $454=5^3+5\cdot4^3+2^3+1^3$.] 121 numbers require 7, the two largest being 5818 and 8042. [$8042=17^3+3\cdot10^3+2\cdot4^3+1^3$.]

Here is a table showing the distribution of the number of cubes required for the numbers 1 to 10,000; then for numbers 19,000 to 20,000; 29,000 to 30,000; 39,000 to 49,000; and finally for 998,000 to 999,000 and 999,000 to 1,000,000.

No. of Cubes.	1.	2.	3.	4.	5.	6.	7.	8.	9.
1–1000	10	41	122	242	293	202	73	15	2
1000–2000	2	27	113	283	358	194	23	0	0
2000–3000	·	·	·	·	·	·	7	0	0
3000–4000	·	·	·	·	·	·	6	0	0
4000–5000	·	·	·	·	·	·	7	0	0
5000–6000	·	·	·	·	·	·	4	0	0
6000–7000	·	·	·	·	·	·	0	0	0
7000–8000	·	·	·	·	·	·	0	0	0
8000–9000	·	·	·	·	·	·	1	0	0
9000–10000	1	17	121	377	401	83	0	0	0
19000–20000	1	12	100	400	426	61	0	0	0
29000–30000	1	11	105	448	388	47	0	0	0
39000–40000	1	13	117	457	384	28	0	0	0
998000–999000	0	1	98	640	262	1	0	0	0
999000–1000000	1	1	94	614	289	1	0	0	0

[*Figures marked · are not worked out.*]

From this table it can be said with some certainty that $g(3)=9$, but the more interesting number $G(3)$, which is known to be > 3, is 4, 5, 6 or 7,

and from the tables would appear to be 4 or 5 or 6, with the possibility that it is 4, in view of the drop in the number of 5-cube numbers and the almost total disappearance of 6-cube numbers. Here 7-cube numbers cease to exist, but it has not yet been *proved* that $G(3) \leqslant 7$.

Maillet in 1895 first proved the existence of $g(3)$, and proved also that $g(3) \leqslant 17$. In 1905 Fleck showed that $g(3) \leqslant 13$, and in 1909 Wieferich proved that $g(3) \leqslant 9$. As two numbers 23 and 239 do require 9 cubes, it is proved that $g(3) = 9$. Take $k = 4$. Liouville in 1859 first proved the existence of $g(4)$ and showed that $g(4) \leqslant 53$. If, however, $n > 81$, it is easy to show from Liouville's proof that $g(4) \leqslant 50$. If $n < 81$, only 19 4th powers are required, noting that $79 = 4 \cdot 2^4 + 15 \cdot 1^4$, and hence $19 \leqslant g(4) \leqslant 50$, and further work on the same lines by Wieferich gave the top limit as 37, reduced later by Dickson by more advanced work to 35. Hence $19 \leqslant g(4) \leqslant 35$. For $G(4)$ it has been proved that its value is 16 or 17.

For higher values of k, it has been shown that $G(5) \leqslant 28$, $G(6) \leqslant 42$, $37 \leqslant g(5) \leqslant 54$, $73 \leqslant g(6) \leqslant 104$.

Even with $k = 3$ or 4 there is yet much work to be done on Waring's problem. Much too is being done on allied problems, the expression of a number as the sum of a series of positive or negative kth powers, the expression of a number as $x^3 + y^3 + z^2$, the expression of a number as x^k + a prime, the number of ways of expressing a number as the sum of kth powers, and so on.

I do not think that Waring ever envisaged the work and the results which have followed from his statements, and he probably does not deserve what Robert Browning said of another Waring,

> . . . "To only have conceived,
> Planned your great works, apart from progress
> Surpasses little works achieved."

Be that as it may, it is certain that while other holders of the Lucasian Chair of Mathematics at Cambridge are forgotten, Edward Waring will always be remembered by many as long as the desire exists to work on pure mathematics for its own results, its own interest, and its own beauty.